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FINAL REPORT

FEASIBILITY AND COST COMPETITIVENESS OF PV/DIESEL GENERATOR HYBRID POWER SYSTEMS FOR ARCTIC SITES

PREPARED FOR:

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EXECUTIVE SUMMARY

Background

Recent years have illustrated that extreme volatility exists in the supply and pricing of petroleum. The effects of this instability are felt very deeply in the north and other areas who rely heavily on diesel generation (gensets) for power supply. With recent forecasts indicating that Canada will become a net importer of light oil as early as 1990 (Canadian Energy: Supply and Demand 1985 - 2005; National Energy Board, 1986) it becomes increasingly important to document and develop methods of lessening or eliminating wherever possible, this dependence on oil as the sole source of electrical power.

Methods of achieving this end must first be identified and studied to explore their potential for application. The purpose of this report is to document the findings of our recent work in simulating the use of several alternative means of power production in locations north of the 60th parallel which are either presently using, or are slated to use, genset type systems.

Method

Work first began by selecting a number of sites located north of 60° latitude for possible inclusion in this study. Several Federal and Territorial government and private agencies were contacted and asked to submit names of locations which they thought might be suitable. From this list 5 main sites were chosen to be representative of a wide variety of sites presently using diesel generation as a prime power supplier in the far north. The variation in each sites' location, geography, weather environment, load requirements, seasonal use, and degree of remoteness were all factors in determining those sites finally selected.

The sites selected were:

1/ Sheep Creek Warden Station
   69° 20' N., 140° 5' W.
   North Yukon National Park, Yukon Territories
   Population - 8 to 10 seasonally
   Average power consumption when occupied - 22 kWh/day
   Cost of fuel on site - $2.32/litre

2/ Stokes Point Warden Station
69° 25' N., 139° 45' W.
North Yukon National Park, Yukon Territories
Population - 3 to 4 seasonally
Average power consumption when occupied - 12.5 kWh/day
Cost of fuel on site - $2.25/litre

3/ Snare Lake
64° 11' N., 114° 11' W., Northwest Territories
Population - 80
Average power consumption - 262 kWh/day
Cost of fuel on site - $0.41/litre

Trout Lake
60° 26' N., 121° 15' W., Northwest Territories
Population - 60
Average power consumption - 218 kWh/day
Cost of fuel on site - $0.41

* These 2 sites were viewed as a composite.

4/ Arctic Red River
67° 27' N., 133° 46' W., Northwest Territories
Population - 120
Average power consumption - 964 kWh/day
Cost of fuel on site - $0.41/litre

Once site selection was completed, work began on sourcing appropriate software for computer simulation of various power system types. The 3 types of systems to be analyzed were:

1/ Genset - standard continuously running diesel generator.
2/ Gencharger - Diesel generator with battery storage.
3/ Photogenset - PV/diesel hybrid with battery storage.

After concluding that there were no available computer programs suitable for simulating the above system types it was decided that one would be created in-house to assist in completion of this contract. The result of these efforts is **SYSTEM-SPEC**^{tm}, Photron's power system design software.

The 3 types of power systems were analyzed and optimized during numerous computer simulation runs in which various equipment sizes and configurations were compared. Through this process an optimized Gencharger and Photogenset system was selected for each of the sites under study. At the conclusion of this work an economic analysis of each system configuration was carried out to demonstrate the potential for application at each site.

Conclusion and Results

The economic comparisons carried out in the main body of this report demonstrated the following:

1/ That Gencharger and Photogenset systems are economically viable and have very short payback periods at this time in sites of a similar size (under 50 kWh/day power requirements) and nature (high fuel costs) to Sheep Creek and Stokes Point.

2/ That, given the present low cost of fuel at the Snare Lake and Arctic Red River sites, the Genset system is the best method of power production at this time for these and similar locations.

3/ That, given the fact that costs for diesel fuel will increase in the near future, Gencharger type systems will be a viable method of power production for an increasing number of sites, including those of a size (200 to 1200 kWh/day power requirements) compared to Snare Lake and Arctic Red River.

1.0 INTRODUCTION

1.1 BACKGROUND

In the past, choosing a means of generating electrical energy in the more remote parts of our country has been a fairly simple matter. Of the relatively few choices in methods available, by far the most common was the application of the diesel generator. Even today in parts of Canada, and throughout the world, the diesel generator is the most common method used for powering towns, villages, resorts, cottages, and industrial sites that have no ready and economical access to the utility-grid system.

The northern regions of Canada are an area of extremes. The first and most notable extreme is environmental in nature (i.e. the weather) and is directly or indirectly the source for many subsequent extremes. The very low population density of the far north coupled with the large distances between communities and developments, large and small, has led to the implementation of diesel fired generation in by far the majority of situations where electrification is desired.

Recent years have illustrated that extreme volatility exists in the supply and pricing of petroleum. The effects of this instability are felt very deeply in the north and other areas who rely heavily on diesel generation for power supply. With recent forecasts indicating that Canada will become a net importer of light oil as early as 1990 (Canadian Energy: Supply and Demand 1985 - 2005; National Energy Board, 1986) it becomes increasingly important to document and develop methods of lessening or eliminating wherever possible, this dependence on oil as the sole source of electrical power.

Methods of achieving this end must first be identified and studied to percieve their potential for application. The purpose of this report is to document the findings of our recent work in simulating the use of several alternative means of power production in locations north of the 60th parallel which are either presently using, or are slated to use, diesel generation.

1.2 SITE IDENTIFICATION AND LOAD ANALYSIS

A number of sites located north of 60° latitude were studied for possible inclusion under the context of this contract. Several Federal and Territorial government and private agencies were

contacted and asked to submit names of locations which they thought might be suitable. From this list 5 main sites were chosen to be representative of a wide variety of sites presently using diesel generation as a prime power supplier in the far north. The variation in each sites' location, geography, weather environment, load requirements, seasonal use, and degree of remoteness were all factors in determining those sites finally selected.

1.2.1 Sheep Creek Warden Station
Location - 69° 20' N., 140° 5' W., Yukon Territories

Sheep Creek Warden Station is a facility operated by Parks Canada in the North Yukon National Park. It is located in the British Mountain Range at the point where Sheep Creek joins with the Firth River before heading north to empty into the Beaufort Sea, just south of Herschel Island. The ranger station is slated for new development and upgrading in the next year to accomodate 8 to 10 staff on a seasonal basis (May 1 to Oct. 31), with occasional occupation by 2 persons for a 1 to 2 day period on a monthly basis throughout the off-season. Even though located at the bottom of a valley, interruption of solar insolation is limited during the seasonal months when major power requirements will occur, because of the high angle of the sun at this time. Fuel delivery is by plane or helicopter only. This factor leads to an estimated on-site fuel cost of $2.32/litre for #2 diesel.

Load projection figures were developed from information obtained during a visit to the site and subsequent discussion with the Park's personnel at their regional head office in Inuvik, NWT. In addition, further load evaluation was possible when proposed building specifications were provided by the Architectural Department of Parks Canada.

The following is a seasonal summary of the projected average daily load requirements for the Sheep Creek Warden Station based on the information provided:

Winter - 0.12 kWh (radio equipment) when unoccupied
- 30 kWh when occupied (2 day/month estimated)

Spring/Fall - 27 kWh

Summer - 15 kWh

The Sheep Creek site was selected for study because it was representative in terms of size, load requirements, and location of many small seasonally occupied communities, resorts, industrial sites, and field research stations located throughout the north.

1.2.2 Stokes Point Warden Station
Location - 69° 25' N., 139° 45' W., Yukon Territories

Stokes Point is another Parks Canada station located within the boundaries of the North Yukon National Park. Although distance is relatively short (70 km.) from Sheep Creek, it is situated in an entirely different environment, being located on the coastline of the Beaufort Sea. The site is scheduled to house 3 to 4 personnel on an occasional basis only throughout the May 1 to Oct. 31 period, but may be occupied for periods as long as 2 to 3 weeks during this season. Off-season site visits will coincide with those of the Sheep Creek site. On-site fuel costs are estimated at $2.25/litre based on final delivery by plane.

Because of the uncertain nature of occupancy at this site (i.e. the potential exists for almost permanent occupancy during the operating season) load projection figures were developed as if the site was continually occupied through the operating season. These figures were developed in the same manner as that utilized for Sheep Creek.

The following is a seasonal summary of the projected average daily load requirements for the Stokes Point Warden Station:

Winter - 0.12 kWh (radio equipment) when unoccupied
- 20 kWh when occupied (2 days/month estimated)

Fall/Spring - 16 kWh

Summer - 7 kWh

The Stokes Point site was selected for study because, while it contained many of the same characteristics already exemplified at Sheep Creek, the smaller load requirements offered a view of differing overall economics for these types of systems.

1.2.3 Snare Lake
Location - 64° 11' N., 114° 11' W., NWT

Trout Lake
Location - 60° 26' N., 121° 15' W., NWT

For the purposes of this report these two sites will be viewed as a composite and will hereinafter be referred to as the Snare Lake site. Utility power was installed at Trout Lake (population 60) in Feb./87, exactly 1 year before the Feb./88 installation of a duplicate system at Snare Lake (population 80). Fuel is trucked in to both sites on winter roads and has an estimated on-site cost of $0.41/litre.

Actual power generation and operating figures were obtained for the 1st year of operation at Trout Lake and have been adjusted to include the somewhat larger expected consumption at Snare Lake along with allowances for increased loads as the community adapts to access to utility power.

The following is a seasonal summary of the projected average daily load requirements for the Snare Lake site and is based on actual power sales (for 1987/1988) as recorded by Northland Utilities:

Winter - 341 kWh

Spring/Fall - 219 kWh

Summer - 225 kWh

The Snare Lake site was selected for study as it is representative of many small communities located throughout the north which are not presently powered by utility type systems.

1.2.4 Arctic Red River
Location - 67° 27' N., 133° 46' W., NWT

Arctic Red River is a community of approximately 120 people located on the MacKenzie River some 120 km. (by road) south of Inuvik. The community's power is supplied by a diesel generator grid system operated by Northern Canada Power Commission (NCPC). Fuel is delivered from Inuvik by truck with on site costs of approximately $0.41/litre.

The following is a seasonal summary of the projected average daily load requirements for the Arctic Red River site:

Winter - 1180 kWh

Spring/Fall - 1024 kWh

Summer - 689 kWh

The Arctic Red River site was selected for study as it represents a somewhat larger northern community with a well established load base. For instance, although the population of the town is only 50% larger than that of Snare Lake, the power consumption figures are over 250% higher on average. This is due to the existence of a much larger industrial facility contingent at Arctic Red River.

1.3 SUMMARIZED TABULATION OF SITE CHARACTERISTICS

Table 1.3 provides a summary of the important characteristics of each site selected for study:

TABLE 1.3 SITE CHARACTERISTICS

SITE NAME	POP#	OCC (1)	FUEL COST (2)	DEL (3)	AVG. DAILY POWER CONS.(4)		
					WINTER	SPRING/FALL	SUMMER
Sheep Creek	10	S	$2.32	A	2.1	27	15
Stokes Point	4	S	$2.25	A	1.5	16	7
Trout Lake(5)	60	C	$0.41	Tw	284	183 (6)	188
Snare Lake(5)	80	C	$0.41	Tw	341	219 (6)	225
Arctic Red R.	120	C	$0.41	T	1180	1024	689

Notes - (1) Occupancy is divided into 2 categories:
1. S - on a seasonal (approximately Apr. 15 to Oct. 31 basis
2. C - on a continuous basis

(2) These fuel costs are ascribed to a Jan./88 average spot market price for crude oil of $17.00 US per barrel and represent the actual cost per litre of #2 diesel after delivery to site.

(3) Methods of fuel delivery are as follows:
A - air delivery by plane
T - delivery by truck over maintained road
Tw- delivery by truck over winter road

(4) Values given represent averages expressed in kWh/day over seasons defined as follows:
Winter - Nov.1 to Feb. 28
Spring/Fall - Mar. 1 to Apr. 30, Sept. 1 to Oct. 31
Summer - May 1 to Aug. 31

(5) These two sites were viewed in composite fashion for the purpose of this report (see Section 1.2.3). The power consumption figures for Trout Lake represent actual values recorded by Northland Utilities (confirmed March, 1988). The figures for Snare Lake represent values as estimated by Northland Utilities (genset installation occured Feb./88).

(6) The anomaly of low power consumption figures during the Spring/Fall season at these sites is the result of significantly reduced population during April and Sept., two periods when a large number of the community's members are traditionally away due to hunting season.

2.0 METHODS

Upon completion of the tasks of site selection and the gathering, compiling, and analysis of load information, work was initiated to document the potential for use of several types of alternative power supply systems at each location respectively.

2.1 POWER SYSTEM DESIGN

There were 5 main system types identified for study under the terms of the original contract. The 5 types were as follows:

A. PV stand alone with battery.
B. PV/diesel hybrid without battery storage.
C. Continuously running diesel (hereinafter referred to as "Genset").
D. Diesel with battery storage (hereinafter referred to as "Gencharger™").
E. PV/diesel hybrid with battery storage (hereinafter referred to as "Photogenset™").

Of the 5 main system types available for study, 3 were to be selected for each site. System types C, D, and E were selected in each case. System types A and B were not deemed to be suitable for use at any of the sites selected for study. Refer to Figures A through E for block diagrams of these system types.

2.1.1 Type A - PV Stand Alone (Figure A)

Stand alone PV/battery systems are proving to be a reliable and cost effective means of providing power to remote sites. This is particularly true in cases where the power requirements are relatively small (under 5 kWh/day) and load patterns are consistent, with no dramatic peaks and valleys. Stand alone PV systems are also proving to be valuable at unmanned sites where personnel are in attendence infrequently. In Canada's far north stand alone PV systems must have provision for excess battery storage capacity ,as little or no solar input will be available during the winter period. In addition to this, if loads are required to be kept operational during the winter period and the battery must operate at ambient temperatures, additional oversizing of the battery must take place due to the characteristic of decreasing available output capacity as the temperature declines.

PV stand alone systems were not deemed to be feasible for any of the sites selected for this study. The required larger battery and PV array sizes could not be justified economically, even at the Stokes Point site which has the lowest daily power requirement figures. (e.g. A simulation run for a PV stand alone system at Stokes Point was carried out which indicated that a 300 kWh battery and 8 kW PV array would be required to maintain required winter radio and monthly site visit operation. In addition it should be noted that a PV array in this configuration would be producing approximately 4 times as much energy than could be consumed during the summer period.)

2.1.2 Type B - PV/Diesel Hybrid Without Battery Storage (Figure B)

This type of system configuration consists of a PV array whose output is directly tied into the on-site AC distribution system through a line commutated DC to AC inverter. In almost all cases such a system requires the continuous operation of the genset to allow for any peak load period

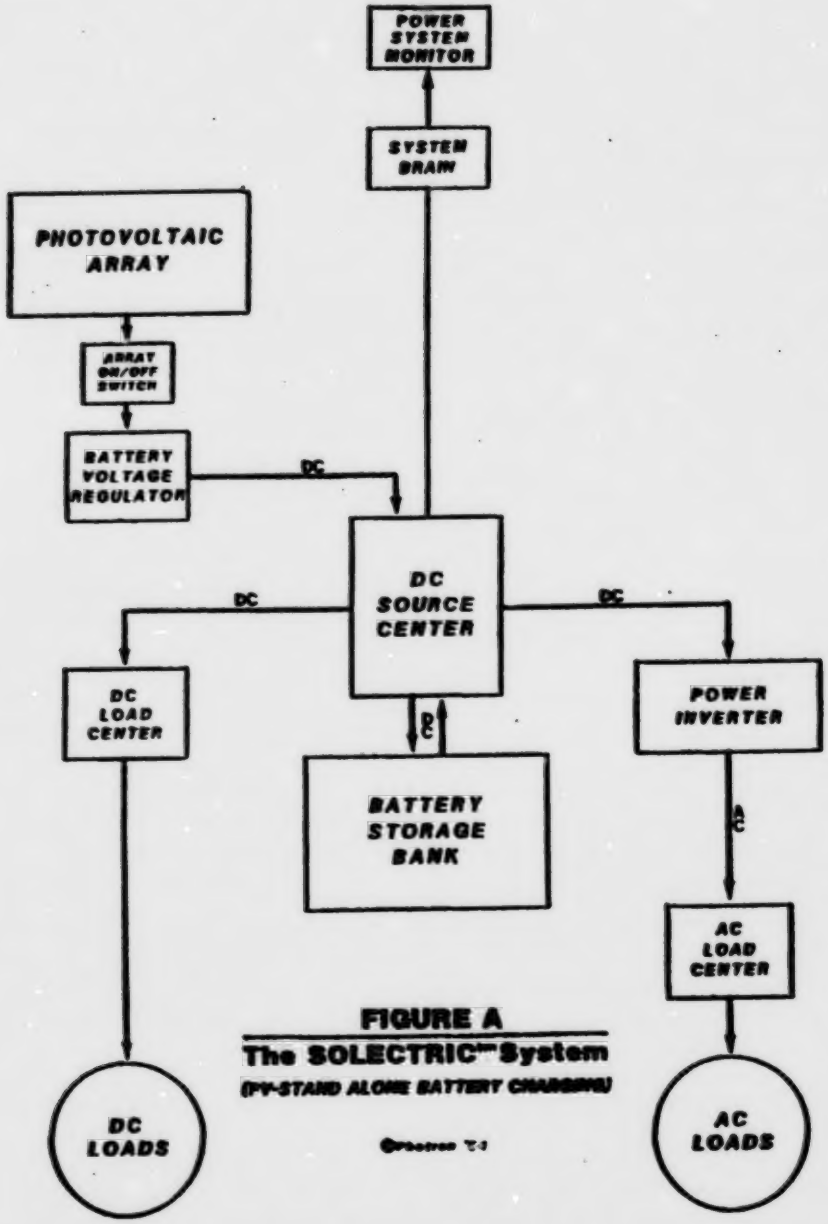

FIGURE A

The SOLECTRIC™ System

(PV-STAND ALONE BATTERY CHARGING)

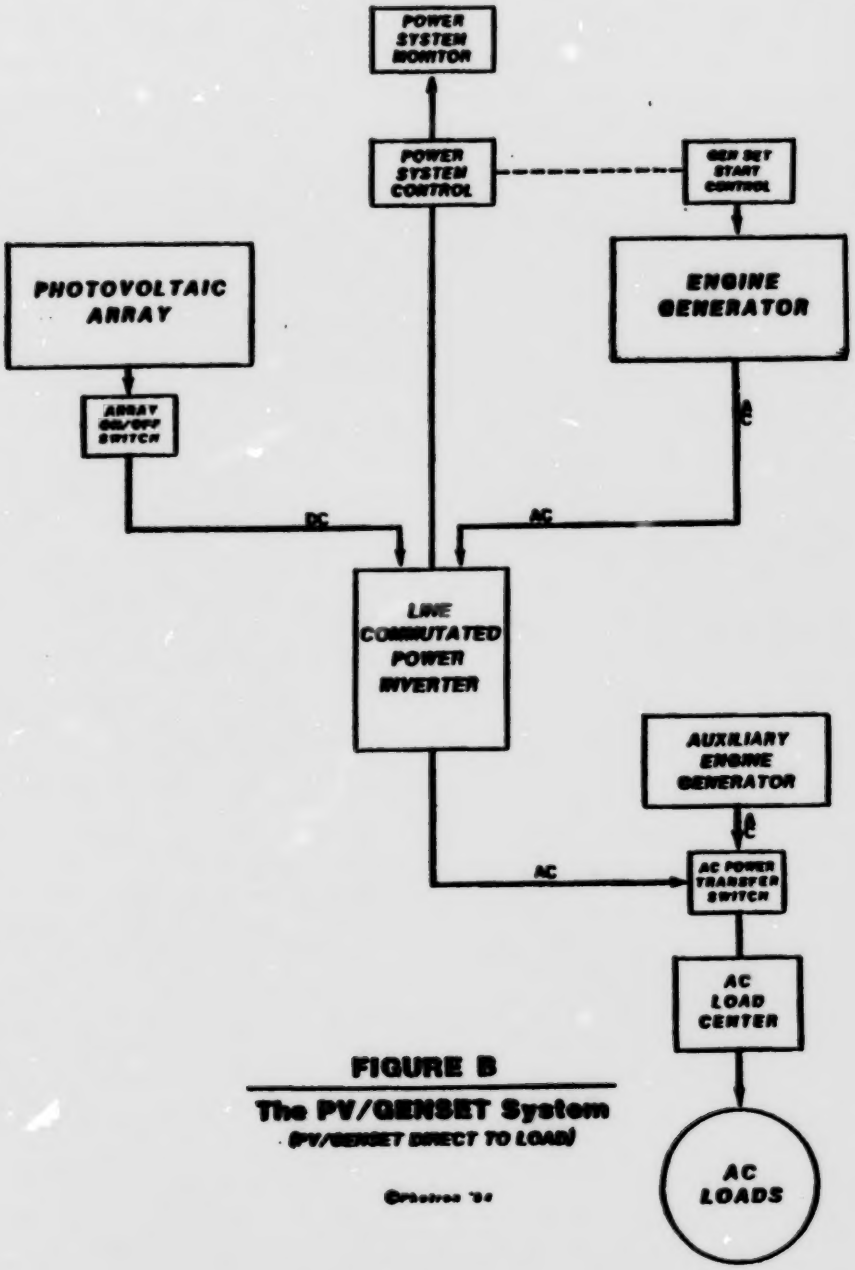

FIGURE B

The PV/GENSET System

(PV/GENSET DIRECT TO LOAD)

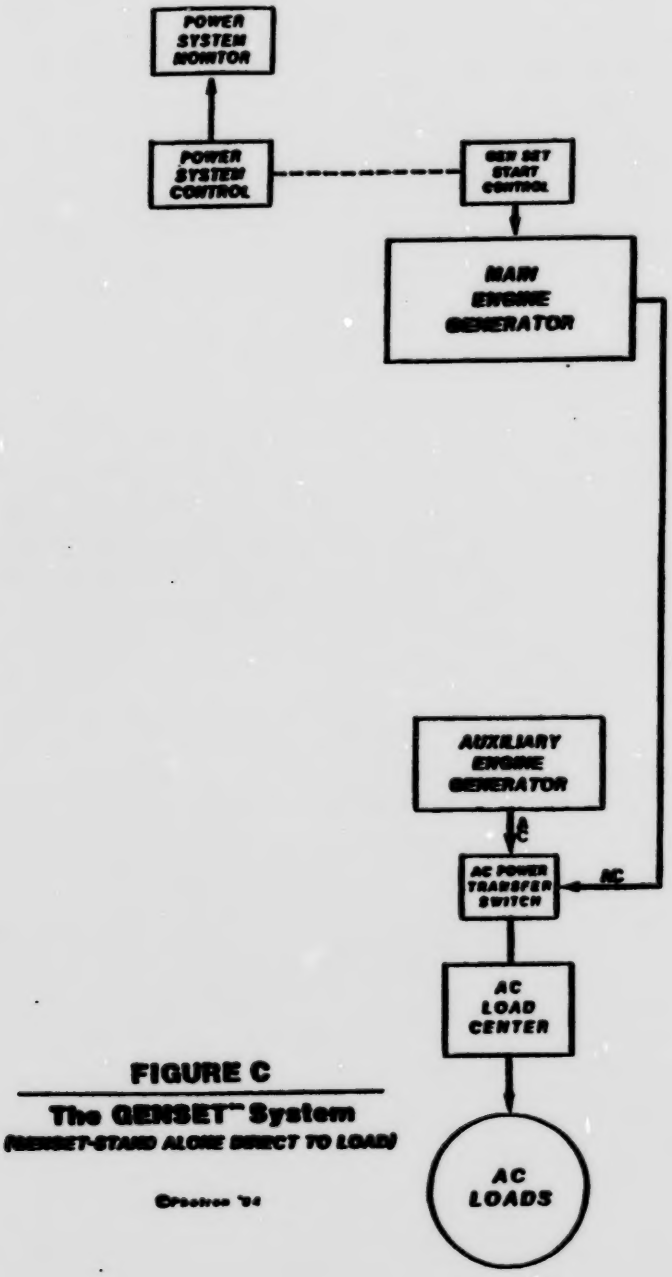

FIGURE C

The GENSET™ System

(GENSET-STAND ALONE DIRECT TO LOAD)

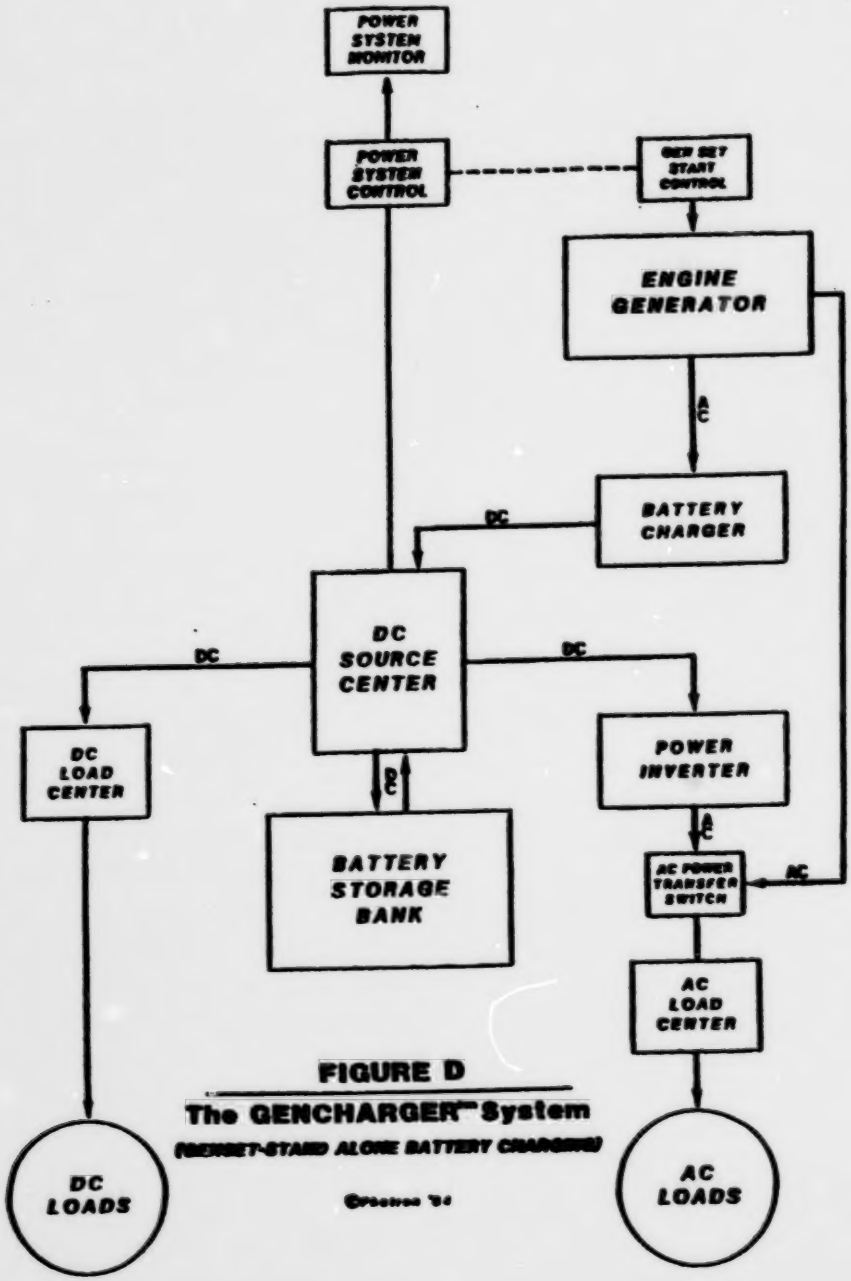

FIGURE D

The GENCHARGER™ System

(GENSET-STAND ALONE BATTERY CHARGER)

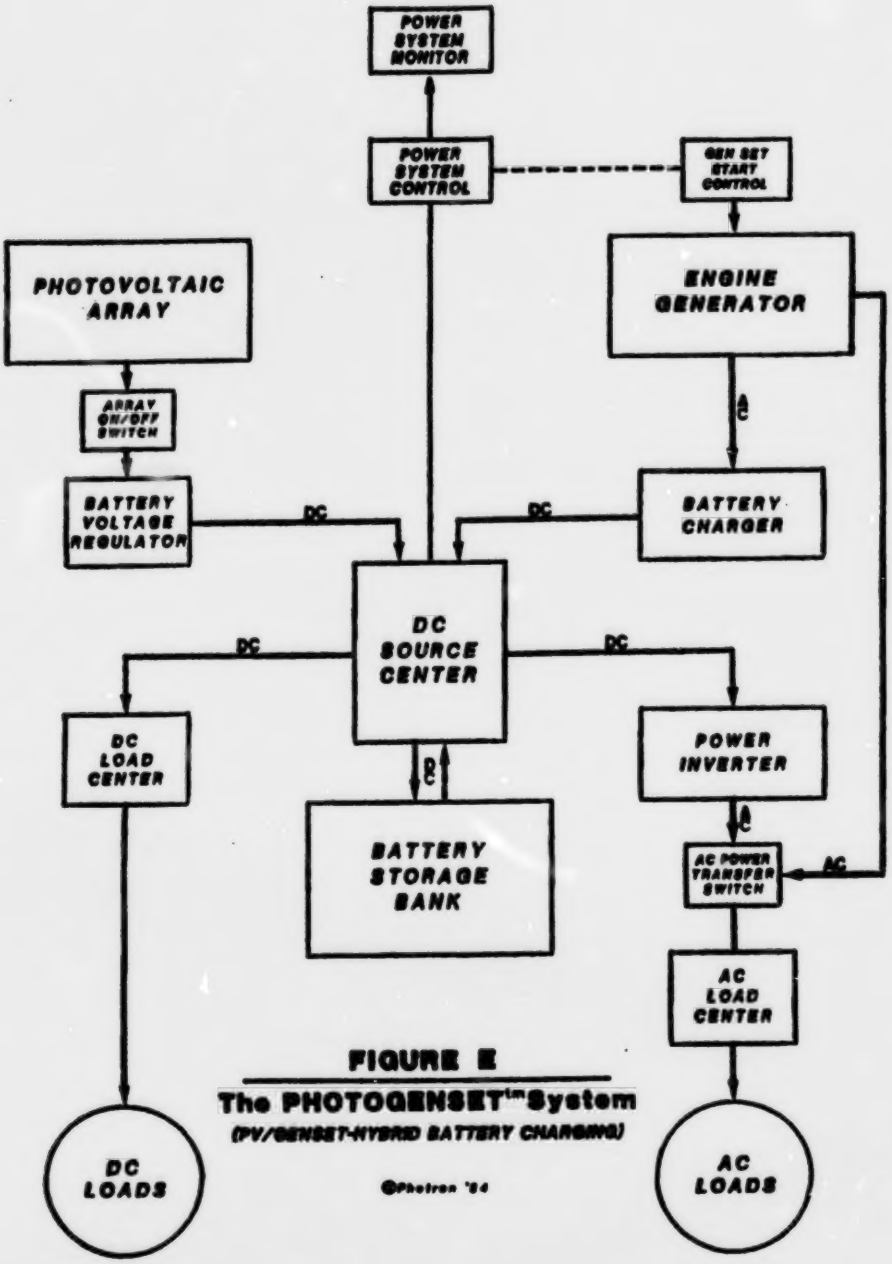

FIGURE E

The PHOTOGENSET™ System

(PV/GENSET-HYBRID BATTERY CHARGING)

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(however brief) and for times when the PV array will not produce to required capacity (i.e. cloudy periods, night time, arctic night, etc.). The only potential for this type of system therefor is in the area of reduced genset fuel consumption, as a result of reduced load requirements whenever the PV array is contributing energy. This issue however is not as plain as it might appear at first glance due to the factor of relative fuel efficiencies resulting from "generator capacity utilization".

A genset operating in a situation of variable loading must be sized to allow for peak load periods. Frequently, in larger remote communities a number of different units of larger and smaller size are utilized according to these peaks and valleys in the daily load profile. In smaller communities and systems this is not a practical alternative due to the following:

- increased capital equipment cost
- potential ratio of average to peak load too extreme

Ideally, gensets should be fully loaded when running, providing maximum fuel-to-electrical conversion efficiency. This not only makes better use of the fuel dollars being consumed to provide for the load service, but results in lower maintenance costs and higher equipment lifespan values as, gensets are "mechanically happier" when running near their rated capacity (see Section 4.0 for further explanation of the term "mechanically happier").

Figure F graphically presents the relationship between genset fuel conversion efficiency and capacity utilization. By adding a PV array to the genset system, fuel efficiency is directly effected by decreasing the amount of site load supplied by the genset unit. As Figure F illustrates, fuel efficiency decreases as the percentage of supplied load is reduced, particularly if the unit is operating at less than 40% of its rated capacity. The benefits of the PV array are therefore brought into serious question. For this reason PV/diesel hybrid systems without battery storage were not deemed to be feasible for any site selected for this study.

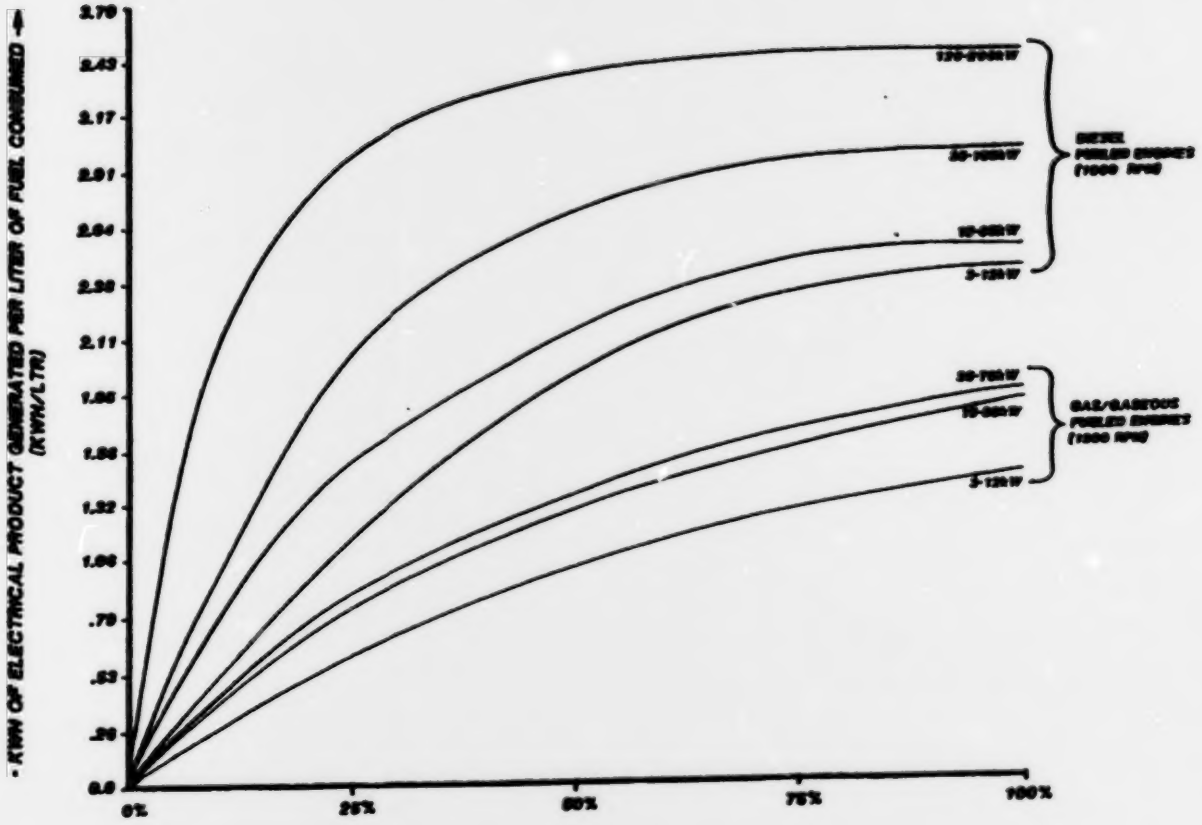

FIGURE F: GEN SET FUEL EFFICIENCY VS CAPACITY UTILIZED

Size Class: 3 To 200kW (Source: Mfr's Published Data For ONAN Gen Sets)

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2.1.3 Type C - Genset (Figure C)

Genset systems are presently operating at Snare Lake and Arctic Red River, and were slated for use at Sheep Creek and Stokes Point. It is not necessary to go into great detail about this system type at this point. The importance of selecting genset systems as one type to be analyzed at each site lies in the economic comparisons derived at a later point in this report.

2.1.4 Type D - Gencharger^{tm} (Figure D)

In the Gencharger system configuration the genset is removed from the task of continuous operation for AC load supply. A battery, battery charger, DC to AC inverter, AC transfer switch, DC service entrance, and control electronics are employed for power supply and supervision. The genset is now utilized to power AC loads and maintain a proper battery state of charge (BSOC). At all other times (typically 75 - 90% of the time) the genset remains deactivated and the normal supply means of all AC site power becomes the system's DC to AC inverter.

The advantages of this system type become immediately recognizable in reduced fuel and maintenance costs for the genset, as well as increased genset lifespan and greatly improved capacity utilization (see Section 2.1.2). Other desirable side effects occur in the resulting decrease in air and noise pollution.

In the case of seasonally unmanned sites such as Sheep Creek and Stokes Point this system type also will allow the added feature of the ability to maintain continuous radio telemetry with the sites through the winter season. This is not practical in the Genset configuration.

The disadvantage of the Gencharger system is primarily one of increased capital cost of equipment. In many systems this disadvantage can be quickly erased as a result of reduced operating costs (see Sections 4.0 and 5.0). Factors which effect the rate of economic return include equipment costs, maintenance costs, component life-spans, and most significantly, site-specific load requirements and fuel costs (see Sections 4.1 and 5.1).

2.1.5 Type E - Photogenset^{tm} (Figure E)

The Photogenset system configuration utilizes the same basic components of the Gencharger system, but includes a PV array with associated mounting and control equipment. The system's battery storage bank recieves additional charging from the PV array in direct proportion to both the array's size and available solar radiation. This in turn helps to extend the period of genset shut down, thereby reducing generator fuel and maintenance costs and extending the units useable lifetime even further.

2.2 SYSTEM DESIGN SOFTWARE

Several computer programs (such as PV FChart, PV Watsun, etc.) are available to assist the system designer in PV system design. It is noted however that these programs for the most part encompass the design of PV stand alone and simple line-tie systems only and were therefore not suitable for use under the context of this contract.

PVFORM, a program developed by Sandia National Laboratories for PV system simulation of stand alone and grid-interactive applications, was procured and evaluated for use in simulation work under this contract. In general the program was found to be well designed, but its practicality for the simulation work necessary to this contract was not felt to be high. PVFORM goes into very great detail in system design and requires a great deal of time and effort in both the input of data and compilation/output mode. These qualities are percieved to be important when one is designing a multi-million dollar facility, but become somewhat less advantageous and necessary as the size of the project decreases. Additionaly, the program requires a significant weather data base that does not exist for the sites in question. Without proper data input there is no possibility for useful data output. Also lacking were provisions for the addition of Gencharger type inputs. It was therefore concluded that the time and effort which would be required in adapting this program could be better spent in the creation of new software specific to not only stand alone PV, but to Gencharger and Photogensets as well.

SYSTEM-SPEC^{tm}, Photron's power system design software, is the result of a significant effort put forth in creating a program that could

fulfill the many and varied tasks in executing the simulation runs required for the successful completion of this report. The copy included with this report is considered to be confidential material and is not for distribution to other parties. The sample copy can be used to verify the data contained in this report if desired, or to run sample simulations for comparative purposes.

2.3 SYSTEM SIMULATION

After development and debugging of the SYSTEM-SPEC software, the task of simulating the various system types at each of the prescribed sites was made much easier and more effective.

During the simulation process a number of system parameters were varied and the results analyzed. The following sections list a number of the factors which were viewed.

2.3.1 Battery Type and Capacity

Battery type was selected arbitrarily. For the Sheep Creek and Stokes Point sites, which will be unmanned and unheated during the winter season, the battery type selected was the GNB Absolyte. Another alternative type would be nickel-cadmium, but this choice was eliminated for the following reasons:

- much higher initial cost
- nickel-cadmium is less efficient than lead acid regardless of the temperature of operation due to:
  - higher self discharge rates
  - lower voltaic efficiency
  - lower coloumbic efficiency

For the Snare Lake and Arctic Red River sites the battery type selected was the industrial type, deep cycling, lead antimony. Other battery types were not perceived to be cost effective in these locations.

Battery capacity is automatically optimized by the SYSTEM-SPEC program. The capacity selection is made using factors such as operating temperature, charge and discharge rates and cycling regime.

2.3.2 PV Array Size

Photogenset PV array size was optimized to ensure that, as far as possible, no dumping or oversupply of PV derived energy would occur throughout the charging season. As PV's are a relatively high cost energy producer, the output of the array should always be performing some useful function (i.e. energy supply). System economics will be adversely effected if, due to improper system design, the array output must be frequently regulated (i.e. capital cost expenditures will be wasted on too large a PV array).

2.3.3 Diesel Generator Capacity

In Photogenset and Gencharger system design the generator size is usually chosen in response to one of two factors. First, there is often a unit (or units) on-site which will be utilized, and second, if no unit is on-site a size will be selected to allow operation at maximum fuel efficiency while minimizing genset run time and providing for peak load requirements.

2.3.4 Control Strategy

In larger Gencharger and Photogenset systems, where a bank of battery charger units can be utilized, a control strategy can be devised to ensure that the generator always remains loaded at 90% capacity or greater. This is done to maximize fuel efficiency through control of genset loading. When operating, the genset supplies all AC site load requirements. Individual battery charger units are then added to or shed from the genset according to available remaining AC capacity. At present, this method is not deemed to be cost effective or necessary in smaller (single battery charger) systems.

SYSTEM-SPEC has the ability to revise calculations to accomodate a continuous +90% generator loading strategy.

2.3.5 PV Array Tracking

There are currently very few choices available in selecting PV array tracking equipment suitable for use in relatively small systems (below 100 kW). Of the types available, a passively activated, single-axis, 8 module unit (manufactured by Zomeworks, of Albequerque, New Mexico) was installed for

testing at Photron Canada's facility during the early stages of this contract. The performance of this unit was monitored from Oct./87 to Feb./88 to evaluate its potential for use in cold climates. The unit did not perform well at temperatures below -10° C. and was not sufficiently adjustable to allow a severe enough seasonal angle adjustment for easy snow-shedding. The unit was also noted to perform poorly in moderately high wind conditions. In warmer conditions the tracker performed reasonably well, operating in insolation conditions as low as 250 W/m^2 and with a maximum 5° lag from normal sun position throughout the day after "wake-up", which occured approximately 1 hour after sunrise.

Also available are mechanically operated units (e.g. Dihn Corp.) but this type is not considered appropriate for the extreme environmental conditions experienced in the north.

For these reasons tracking arrays were deemed to be unviable at present for all sites selected for study. Seasonably adjustable, true south-facing, fixed arrays were instead used for all PV array output calculations.

3.0 RESULTS

3.1 SYSTEM OPTIMIZATION

System optimization work was carried out on both the Gencharger and Photogenset type systems for each site. To demonstrate the method of optimization used in making the recommendations for this report, a series of computer print outs on the Stokes Point system are included in the Appendix. Optimizing for all other sites was carried out while working back and forth through the SYSTEM-SPEC program. A single design and report print out of the optimized Gencharger and Photogenset systems for these sites is also included in the Appendix.

3.1.1 Stokes Point Photogenset Optimizing

A print out of both the initial design parameters and the output report for the Stokes Point Photogenset system (#STOKES-3.00) is included in the Appendix for reference.

The PV array size, size of battery bank, and size of the battery charger were all selected automatically by the program as per the design inputs. This design shows an annual operating cost estimate (Line 3.1, Design Report) of $2,695.00/yr. with a PV array size of 1.882 kW.

Several runs were made with revised PV array sizes to view the effect on system economics. In Design Report #STOKES-3.01 a reduced PV array size to 1.505 kW was shown to add $77.00/yr. to the operating cost but lowers the capital cost of equipment by approximately $3000.00 . In Design Report #STOKES-3.03 a reduced PV array size to .941 kW was shown to add $673.00/yr. to the operating cost while lowering the capital cost of equipment by approximately $7500.00 . No design runs with increased PV array size were carried out as per the design rule previously stated in Section 2.3.2 of this report.

In Design Report #STOKES-3.02 a smaller generator (6 kW as opposed to 15 kW) was simulated. This change can be seen to add $886.00/yr. to operating costs while lowering the capital cost of equipment by $7500.00 .

From the above information, design #STOKES-3.01 was selected as the Photogenset system showing the best overall economic performance for the Stokes Point Site.

3.1.2 Stokes Point Gencharger Optimizing

A printout of both the initial design parameters and the output report for the Stokes Point Gencharger system (#STOKES-2.02) is included in the Appendix for reference.

Several runs were made with revised generator sizes to view the effect on system economics. In Design Report #STOKES-2.00 the reduced generator output rating of 6 kW was shown to add $1396.00/yr. to operating costs while lowering the capital cost of equipment by $4500.00 . In Design Report #STOKES-2.03 the increased generator output rating of 23 kW was shown to lower operating costs by $190.00/yr. while adding approximately $18,500.00 to the capital cost of equipment (due to increased battery and charger sizes).

From the above information, design #STOKES-2.02 was selected as the Gencharger system showing the best overall economic performance at the Stokes Point site.

3.2 STOKES POINT OPTIMIZING TABLE

Table 3.2 serves to illustrate the Stokes Point optimizing process as described above:

TABLE 3.2 STOKES POINT OPTIMIZING (1)

REPORT #	EQUIPMENT SIZE (2)				CAPITAL COST	ANNUAL OPERATING $
	PV Array	Battery	Charger	Genset		
Stokes-3.00	1.88	45	10.9	15	$58500	$2695
-3.01	1.51	45	10.9	15	55500	2772
-3.02	1.51	43.3	3.8	6	51000	3581
-3.03	.94	45	10.9	15	51000	3368
Stokes-2.00	----	43.3	4.1	6	38000	5797
-2.02	----	48.6	10.9	15	42500	4401
-2.03	----	76.1	18.5	23	61000	4211

Notes - (1) Optimization of all listed components, except the PV array can be performed by the SYSTEM-SPEC program.

(2) All values given are in kW and express manufacturer's peak ratings under normal operating conditions, with the exception of the battery which is rated @ manufacturer's nominal output capacity (expressed in kWh).

3.3 OPTIMIZED COMPONENT SUMMARY

Table 3.3 offers a summary listing of the optimized major system components for each site:

TABLE 3.3 OPTIMIZED SYSTEM COMPONENT SUMMARY

SYSTEM DESIGN #	EQUIPMENT SIZE (1)					ANNUAL GENSET DATA		
	PV ARRAY	BATT	CHARG	INVR	GENST	FUEL(2) CONSUMP	HRS OPERATN	DUTY (3) CYCLE
Stokes-Genset	----	---	---	--	7.5	8160	4800	55
-2.02	----	48.6	10.9	2.7	15	1803	489	6
-3.01	1.51	45	10.9	2.7	15	1134	305	4
Sheep -Genset	----	---	---	--	15	10800	4800	55
-2A01	----	45	10.9	5.7	15	3075	784	9
-3A01	3.38	48.6	10.9	5.7	15	1720	437	5
Snare -Genset	----	---	---	--	35	56320	8760	100
-2.01	----	225	92.1	24	82.5	26634	1734	20
-1.01	36.69	225	92.1	24	82.5	19063	1239	14
Arcred-Genset	----	---	---	--	100	160000	8760	100
-2.00	----	329	179.4	60	150	113816	2908	33
-1.00	168.03	329	179.4	60	150	78216	1990	23

Notes - (1) All values given are in kW and express manufacturer's peak ratings under normal operating conditions, with the exception of the battery which is rated @ manufacturer's nominal output capacity (expressed in kWh).

(2) Expressed in litres.

(3) Expressed as the percentage of estimated run time per year.

4.0 ECONOMIC ANALYSIS

In this section of the report we will document economic and performance comparisons between the Genset system, and optimized Gencharger and Photogenset systems for each site.

For the purpose of clarification, certain operating postulations* were made in forming a base for economic comparison. These consist of:

	System Type**	
	C	D & E
1/ Time between scheduled genset maintenance for all system types (in hours)	340	340
2/ Time between scheduled genset overhaul for all system types (in hours)	15000	25000
3/ Time between scheduled genset replacement for all system types (in hours)	45000	50000
4/ Minimum life cycle rating on all Gencharger and Photogenset system components except the generator and batteries (in years)	20	20

* Note that these assumptions are dependent on many site and operation specific variables, and are therefore highly volatile. Values expressed represent information as obtained from the before noted utility companies, individual operators, genset manufacturers, and our own field experience.

** The different values between Type C (Genset) and Type D & E (Gencharger and Photogenset) systems are due to known factors of genset operation at differing rates of loading or capacity utilizaton. (i.e. The operating temperature for a genset running at low capacity utilization is below that specified for operation at rated capacity. The consequence of this is higher than normal carbon accumulation due to incomplete fuel burn. This in turn leads to plugging of valve intake and exhaust ports, cylinder wall glazing, etc. Higher maintenance schedules and shorter equipment lifespans result.)

4.1 TABULATION OF SYSTEM ECONOMIC PARAMETERS

The following table summarizes the economic and performance comparisons carried out on the optimized systems selected for each site. Annual operating cost calculations for all systems are illustrated in Sections 4.2 to 4.5 .

TABLE 4.1 OPTIMIZED SYSTEM ECONOMIC SUMMARY

(2) SYSTEM DESIGN #	ECONOMIC PARAMETERS (1)							
	(3) CC $	(4) AOC $	(5) 20C $	(6) Pt yr.	(7) 20R $	(8) 20Rp %	(9) 20Ri $	(10) 20Rip %
Stokes-Genset	12	22	452	----	----	----	----	-----
-2.02	42.5	4.4	130.5	1.73	321.5	37.8	170.3	20
-3.01	55.5	2.77	110.9	2.26	341.1	30.7	180.7	16.3
Sheep -Genset	15.5	30.1	617.5	----	----	----	----	-----
-2A01	49.5	9.5	239.5	1.65	378	38.2	200.2	20.2
-3A01	74.5	4.37	161.9	2.29	455.6	30.6	241.3	16.2
Snare -Genset	90	38.95	869	----	----	----	----	-----
-2.01	225	25.25	730	9.85	139	3.1	73.6	1.6
-1.01	540	18.16	903.2	----	----	----	----	-----
Arcred-Genset	110	89.28	1895.6	----	----	----	----	-----
-2.00	378	80.02	1978.4	----	----	----	----	-----
-1.00	1565	55.06	2666.2	----	----	----	----	-----

Notes - (1) Values are expressed in Canadian Dollars x 1000 wherever $ sign heads column

(2) The order of recording (i.e. Genset, Gencharger, Photogenset) is maintained throughout.

(3) CC = Capital cost of system

(4) AOC = Annual operating cost of system

(5) 20C = 20 year total cost of system operation calculated as follows:

CC + (20 x AOC)

(6) Pt = Payback period in years (Gencharger and Photogenset systems only) calculated as follows:

[CC (of system type) - Reference system (Genset) CC] ÷
[Reference system (Genset) AOC - AOC (of system type)]

(7) 20R = 20 year return on investment @ 0% discount rate calculated as follows:

Reference system (Genset) 20C - 20C (of system type)

(8) 20Rp = 20 year return on investment @ 0% discount rate expressed in % per annum. Calculated as follows:

(20R ÷ CC) x (100 ÷ 20)

(9) 20Ri = 20 year return on investment @ 7% discount rate expressed in 1988 $. Calculated as follows:

(20R ÷ 20) x 10.594

(10) 20Rip = 20 year return on investment @ 7% discount rate expressed in % per annum. Calculated as follows:

(20Ri ÷ CC) x (100 ÷ 20)

4.2 STOKES POINT ANNUAL SYSTEM OPERATING COSTS

4.2.1 Genset Operating Cost Calculations

* Based on use of a 7.5 kW unit to allow for peak load capacity.

- Annual hr. of genset operation
  @ 200 day/yr x 24 hr - 4800 hr
- Annual estimated fuel consumption
  @ 1.7 lit/hr x 4800 hr - 8,160 lit

- Annual fuel cost @ $2.25/lit x 8160 lit =$18,360.00
- Annual maintenance cost @ (4800 ÷ 340) x $100 = 1,412.00
- Amortized 1st year of genset overhaul schedule = 1,280.00
- Amortized 1st year of genset replacement sched. = 1,013.00

TOTAL ANNUAL COST OF OPERATION $22,065.00

4.2.2 Gencharger Operating Cost Calculations

- Per line 3.1 of STOKES-2.02 Report =$ 4,401.00
- No additional figures for battery or generator replacement as both exceed 20 year minimums. =

TOTAL ANNUAL COST OF OPERATION $ 4,401.00

4.2.3 Photogenset Operating Cost Calculations

- Per line 3.1 of STOKES-3.01 Report =$ 2,772.00
- No additional figures for battery or generator replacement as both exceed 20 year minimums.

TOTAL ANNUAL COST OF OPERATION $ 2,772.00

4.3 SHEEP CREEK ANNUAL SYSTEM OPERATING COSTS

4.3.1 Genset Operating Cost Calculations

* Based on use of a 15 kW unit to allow for peak load capacity.

- Annual hr. of genset operation @ 200 day/yr x 24 hr = 4800 hr
- Annual estimated fuel consumption @ 2.25 lit/hr x 4800 hr =10,800 lit

- Annual fuel cost @ $2.32/lit x 10,800 lit =$25,056.00
- Annual maintenance cost @ (4800 ÷ 340) x $150 = 2,118.00
- Amortized 1st yr of genset overhaul schedule = 1,600.00
- Amortized 1st yr of genset replacement schedule = 1,387.00

TOTAL ANNUAL COST OF OPERATION $30,161.00

4.3.2 Gencharger Operating Cost Calculations

- Per line 3.1 of SHEEP-2A.01 Report	=$ 7,817.00
- Plus amortized battery replacement costs based on 11 yr service life	= 1,637.00
TOTAL ANNUAL COST OF OPERATION	$ 9,454.00

4.3.3 Photogenset Operating Cost Calculations

- Per line 3.1 of SHEEP-3A.01 Report	=$ 4,372.00
- No additional figures for battery or generator replacement as both exceed 20 year minimums	=
TOTAL ANNUAL COST OF OPERATION	$ 4,372.00

4.4 SNARE LAKE ANNUAL OPERATING COSTS

4.4.1 Genset Operating Cost Calculations

* Based on use of a 35 kW unit to allow for peak load capacity.

- Annual fuel cost @ $0.41/lit x 56,320 lit	=$23,091.00
- Annual maintenance cost @ (8760 ÷ 340) x $200	= 5,153.00
- Amortized 1st yr of genset overhaul schedule	= 5,840.00
- Amortized 1st yr of genset replacement schedule	= 4,867.00
TOTAL ANNUAL COST OF OPERATION	$38,951.00

4.4.2 Gencharger Operating Cost Calculations

- Per line 3.1 of SNARE-02.01 Report	=$13,501.00
- Plus amortized battery replacement costs based on 4.4 yr service life	= 11,750.00
TOTAL ANNUAL COST OF OPERATION	$25,251.00

4.4.3 Photogenset Operating Cost Calculations

- Per line 3.1 of SNARE-01.01 Report	=$ 9,660.00
- Plus battery replacement cost based on 5.9 yr service life	= 8,500.00
TOTAL ANNUAL COST OF OPERATION	$18,160.00

4.5 ARCTIC RED RIVER ANNUAL OPERATING COSTS

4.5.1 Genset Operating Cost Calculations

* Based on use of a 100 kW unit to allow for peak load capacity.

- Annual fuel cost @ $0.416/lit x 160,000 lit	=$ 66,560.00
- Annual maintenance cost @ (8760 ÷ 340) x $300	= 7,729.00
- Amortized 1st yr of genset overhaul schedule	= 8,760.00
- Amortized 1st yr of genset replacement schedule	= 6,229.00
TOTAL ANNUAL COST OF OPERATION	$ 89,278.00

4.5.2 Gencharger Operating Cost Calculations

- Per line 3.1 of ARCRED02.0 Report	=$ 53,518.00
- Plus amortized battery replacement costs based on 2.9 yr service life	= 26,500.00
TOTAL ANNUAL COST OF OPERATION	$ 80,018.00

4.5.3 Photogenset Operating Cost Calculations

- Per line 3.1 of ARCRED01.0 Report	=$ 36,762.00
- Plus battery replacement costs based on a 3.9 yr service life	= 18,300.00
TOTAL ANNUAL COST OF OPERATION	$ 55,062.00

4.6 RESULTS AND RECOMMENDATIONS BASED ON CURRENT ECONOMICS

Based on the economic performance listed in the above sections, the following recommendations can be made:

1/ Both the Gencharger and Photogenset systems will achieve excellent economic results at sites (similar to Stokes Point and Sheep Creek) that have relatively high on-site fuel costs and low (under 50 kWh/day) power requirements. Gencharger systems demonstrate faster payback periods at these sites while Photogenset systems show a higher return on investment in dollar values.

2/ The existing Genset systems at Snare Lake and Arctic Red River achieve the best economic results for these locations under present conditions. This is due to inexpensive fuel costs, potentially efficient loading, and (in the case of comparison to Photogensets) relatively high costs for PV.

3/ It is important that various government agencies, institutions, industrial operations, and individuals which are presently managing (or are planning) sites which have similar characteristics to Stokes Point or Sheep Creek be made aware of the results of this report. Actual installation of several Gencharger and Photogenset type systems should be encouraged and supported to demonstrate the viability of such systems in northern locations.

5.0 FUTURE ECONOMIC PROJECTIONS

The economic examinations performed in the above sections were based on present day values of two very important components that have every potential of substantial change in cost in the next 5 years. These two components are the PV array and diesel fuel.

Present costs of the PV component (as were applied in the capital cost calculations of this report) range from $5.75/watt (Canadian $) for large scale arrays, such as would be required at Arctic Red River, to $7.25/watt for smaller systems. Current industry projections for future price decreases indicate that prices in the range of $2.75/watt are not unrealistic by the year 1993. On the other side of the coin it is recognized that it is highly improbable for the current low oil prices to extend into this time frame.

It is therefore useful to show system cost comparisons that will, in all probability, be realistic in a few years time. Design simulations were performed according to the following variables:

- an approximate 50% drop in cost for PV and 120% increase in fuel cost for Stokes Point and Sheep Creek (i.e. values were affixed @ $3.50/watt and $5.00/litre respectively).

- an approximate 50% drop in cost for PV and 150% increase in fuel cost for Snare Lake and Arctic Red River (i.e. values were affixed @ $2.75/watt and $1.00/litre respectively).

- an approximate 50% drop in cost for PV and 400% increase in fuel cost for Snare Lake and Arctic Red River (i.e. values were affixed @ $2.75/watt and $2.00/litre respectively).

5.1 FUTURE ECONOMIC PROJECTION TABULATION

TABLE 5.1 FUTURE ECONOMIC PROJECTIONS*

(2) SYSTEM DESIGN #	ECONOMIC PARAMETERS (1)							
	(3) CC $	(4) AOC $	(5) 20C $	(6) Pt yr.	(7) 20R $	(8) 20Rp %	(9) 20Ri $	(10) 20Rip %
(@ $5.00/lit)								
Stokes-Genset	12	44.5	902	----	----	----	----	----
-2.05	42.5	9.35	229.5	0.87	672.5	79.1	356.2	41.9
-3.04	49.5	5.89	167.3	0.97	734.7	74.2	389.2	39.3
Sheep -Genset	15.5	57.8	1170.6	----	----	----	----	----
-2A02	49.5	17.67	353.9	0.85	816.7	82.5	432.6	43.7
-3A02	62	8.98	241.6	0.95	929	74.9	492.1	39.7
(@ $1.00/lit)								
Snare -Genset	90	72.18	1533.6	----	----	----	----	----
-2.02	225	40.96	1044.2	4.32	489.4	10.87	259.2	5.8
-1.02	425	29.4	1013.1	7.83	520.5	6.1	275.7	3.2
Arcred-Genset	110	182.7	3764.4	----	----	----	----	----
-2.01	378	146.5	3308	7.4	456.4	6.04	241.8	3.2
-1.01	1030	99.9	3027.5	11.1	736.9	3.6	390.3	1.9
(@ $2.00/lit)								
Snare -Genset	90	128.5	2660	----	----	----	----	----
-2.03	225	67.6	1577	2.2	1103	24.5	584.3	12.9
-1.03	425	48.5	1394.4	4.2	1265.6	14.9	670.4	7.9
Arcred-Genset	110	342.7	6964.4	----	----	----	----	----
-2.02	378	260.3	5206.4	3.3	1758	21.6	931.2	6.1
-1.02	1030	178.9	4608.8	5.6	2355.6	11.4	1247.8	6.1

* All notes from Table 4.1 apply as listed.

5.2 RESULTS AND RECOMMENDATIONS BASED ON FUTURE ECONOMICS

1/ It can be seen in the above Table 5.1 that the potential for use of Gencharger and Photogenset type systems at all of the locations studied becomes increasingly realistic as the price of fuel increases and the cost of PV decreases.

2/ Gencharger type systems show the fastest payback and higher annual return on investment percentage in all future economic scenarios studied. At the Snare Lake site, the Gencharger system is shown to have attractive payback and return on investment figures at a fuel cost of $1.00/litre. A fuel cost of $2.00/litre creates excellent payback and return on investment figures for Gencharger systems at both the Snare Lake and Arctic Red River sites. Photogenset type systems with reduced cost PV ($2.75/watt) become economically viable at Snare Lake and Arctic Red River at a fuel cost of $2.00/litre and show a higher return on investment in dollar value at all locations.

3/ The economic viability of Gencharger type systems is dependent on the increased cost of fuel and is not affected by the potential decrease in cost of PV (however realistic this potential may be). As indicated earlier in this report (see Section 1.1) fuel costs will definitely rise in the near future. It is therefore recommended that work be carried out to identify communities with load profiles similar to those existing at Snare Lake and Arctic Red River (200 to 1200 kWh/day), and which presently have high fuel costs. Installation of a Gencharger type system should then take place to confirm the indications of this report. Work done in the present will ensure a more secure economic future for the remote communities of Canada's north.

5.3 FURTHER PROJECTIONS FOR REDUCED COST PV

To establish if, at larger sites (200 to 1200 kWh/day power requirements), Photogenset systems will become competetive with Gencharger systems at some point (i.e. at a certain cost/watt for PV), economic evaluations were performed for the Snare Lake and Arctic Red River sites with fuel costs at $1.00 and $2.00/litre, and with the cost for the PV component further reduced to $1.35/watt. The results of these calculations are shown below in Table 5.3:

TABLE 5.3 FUTURE PROJECTIONS WITH PV AT $1.35/WATT*

(2) SYSTEM DESIGN #	ECONOMIC PARAMETERS (1)							
	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	CC $	AOC $	20C $	Pt yr.	20R $	20Rp %	20Ri $	20Rip %
(@ $1.00/lit)								
Snare -1.02	310	29.4	898	5.14	635.6	10.25	336.7	5.4
Arcred-1.01	495	99.9	2493	4.65	1271.4	12.84	674.5	6.8
(@ $2.00/lit)								
Snare -1.03	310	48.5	1280	2.75	1380	22.26	730.9	11.8
Arcred-1.02	495	178.9	4073	2.35	2891.4	29.2	1531.6	15.5

* All notes from Table 4.1 apply as listed.

The results shown in Table 5.3 indicate that, given a reduced cost for PV to $1.35/watt and an on-site cost for fuel of $1.00/litre or higher, Photogenset type systems become an economically attractive method of power production at sites with load profiles similar to those existing at Snare Lake and Arctic Red River.

APPENDIX

THIS APPENDIX HAS BEEN ABBREVIATED TO LOWER REPRODUCTION COSTS. ONLY FOUR SYSTEM DESIGN PRINTOUTS HAVE BEEN INCLUDED.

STOKES 2.02: OPTIMIZED GENCHARGER (tm) SYSTEM

STOKES 3.00: INITIAL PHOTOGENSET (tm) SYSTEM

STOKES 3.01: OPTIMIZED PHOTOGENSET (tm) SYSTEM

SNARE 1.01: OPTIMIZED PHOTOGENSET (tm) SYSTEM

STOKES 2.02: OPTIMIZED GENCHARGER (tm) SYSTEM

Section A: Clerical Data

1.	Design company	: PHOTRON CANADA INC.
2.	Name of designer	: RLL
3.	Design number	: STOKES-2
4.	Design date	: 88 MR 04
5.	Revision number	: 02
6.	Revision date	: 88 MR 04
7.	Client name	: PARKS CANADA
8.	Site name	: Stokes Point Warden Station
9.	Type of system	: Gencharger (tm) GenSet hybrid
10.	Design notes 1	: Initial system sizing.
11.	2	: Sizing allows for use of (1) 24 VDC freezer unit.
12.	3	: Battery state of charge operating regime @ 20-80%.
13.	4	:
14.	5	:
15.	6	:
16.	7	:
17.	8	:
18.	9	:

Section B: Load Data

1.	Required daily DC load energy:	- winter	:	0.43 MJ/d DC
2.		- spring/autumn	:	5.40 MJ/d DC
3.		- summer	:	5.40 MJ/d DC
4.	Required daily AC load energy	- winter	:	3.60 MJ/d AC
5.		- spring/autumn	:	52.20 MJ/d AC
6.		- summer	:	19.80 MJ/d AC

Section C: Generator Set Data

1.	Size of generator set ('genset')	: 15 kW AC
2.	Genset electrical output	: 120/240 VAC, single phase, 60 Hz
3.	Elevation of Stokes Point Warden Statio	: 30 m above sea level
4.	Genset output derating factor	: 0 %
5.	Reason for genset derating factor	: No derating factor
6.	Type of fuel used in genset	: #2 diesel
7.	Genset #2 diesel - at no load	: 1.90 litres/hour
8.	consumption: - at 25% load	: 2.25 litres/hour
9.	- at 50% load	: 2.80 litres/hour
10.	- at 75% load	: 3.70 litres/hour
11.	- at 100% load	: 4.70 litres/hour

12.	Price of #2 diesel at Stokes Point Ward	: 2.250 $/litre
13.	Genset - routine maintenance	: 100 $ per interval
14.	maintenance - overhaul	: 5,000 $ per overhaul
15.	costs: - total replacement	: 11,500 $ per replacement
16.	Genset - routine maintenance	: 340 hours
17.	maintenance - overhaul	: 25,000 hours
18.	intervals: - total replacement	: 50,000 hours
19.	Fraction of total AC load directly connected to the running genset	: 100 %

Section D: Inverter Data

1.	AC loads will be supplied by	: an inverter
2.	Number of non-synchronized inverter modules	: 1
3.	Total 30 minute power rating for all inverter modules combined	: 2.7 kW AC

Inverter module electrical characteristics

4.	10 second surge rating	: 6 kW AC
5.	Average DC to AC conversion efficiency	: 90 %
6.	Nominal DC input voltage	: 48 volts DC
7.	Electrical output	: 120 VAC, single phase, 60 Hz
8.	Low DC input voltage cutoff threshold	: 42 volts DC

Section E: Photovoltaic Data

The power supply at Stokes Point Warden Station is a Gencharger (tm) GenSet hybrid system as selected on line 9 of Section A.

A photovoltaic array is therefore not installed.

Section F: Battery and Battery Charger Data

1.	Number of series-wired 2 VDC (nominal) battery cells	: 24
2.	Battery state of charge (BSOC) - started	: 20.0 %
3.	thresholds at which the genset is: - stopped	: 80.0 %
4.	Average ambient air temperatures - winter	: -25.0 C
5.	that the battery bank will - spring/autumn	: 20.0 C
6.	experience: - summer	: 25.0 C
7.	Method of determining the size of the battery bank	: specified
8.	Total desired 25 C battery bank size at the 6 hour discharge rate	: 1,050 amp-hrs DC
9.	Specialized genset continuous loading control stategy	: none
	SYSTEM-SPEC will calculate an optimum size for the Gencharger	
10.	Method of sizing the Gencharger	: automatic

SYSTEM-SPEC will calculate an optimum size for the Gencharger

Designed by	: PHOTRON CANADA INC.
Design number	: STOKES-2
Revision number	: 02
Name of designer	: RLL
Effective date	: 88 MR 04
Client name	: PARKS CANADA
Site name	: Stokes Point Warden Station
Site elevation	: 30 m above sea level
Type of system	: Gencharger (tm) GenSet hybrid

The following design report was prepared for you with SYSTEM-SPEC (tm), Photron's Power System Design Software. All figures expressed are design averages, except where specifically noted otherwise.

1.0 PRIME COMPONENT SUMMARY

1.1 Photovoltaic ('PV') Array
- DC energy source powered by solar radiation

The power supply at Stokes Point Warden Station is a Gencharger (tm) GenSet hybrid system. A photovoltaic array was not installed.

1.2 Engine Generator ('Gen Set')
- AC energy source powered by fossil fuel

1. Manufacturer's nominal peak power output rating		: 15 kW AC
2. Site installed peak power output rating*		: 15 kW AC
3. AC output power configuration	: 120/240 VAC, single phase, 60 Hz	
4. Type of fuel used		: #2 diesel
5. Specified operating regime: generator	starts at	: 20.0 %
	stops at	: 80.0 %

*Note: In accordance with genset manufacturer specifications, this value has been derated for the elevation at Stokes Point Warden Station.

1.0 PRIME COMPONENT SUMMARY (continued)

1.3 Gencharger (tm)
- DC energy source powered by the GenSet (AC to DC converter)
1. Manufacturer's nominal peak power output rating : 10.9 kW DC
2. Site installed average power output rating : 8.7 kW DC
3. AC input power configuration : 240 VAC, single phase, 60 Hz

---

1.4 Battery Storage Bank
- storage medium for DC energy
1. Manufacturer's nominal 25 C 6 h capacity rating : 175 MJ DC
2. Minimum site installed capacity rating : 169 MJ DC
3. Total number of cells per series string : 24
4. Typical state of charge operating regime : 20 to 80 %

1.5 Power Inverter
- AC energy source powered by DC electricity (DC to AC converter)
1. Manufacturer's nominal peak output rating at 25 C:
   30 minute continuous power : 2.7 kW AC
   10 second surge power : 6 kW AC
2. Number of non-synchronized inverter units : 1
3. AC output power configuration : 120 VAC, single phase, 60 Hz
4. Nominal DC input voltage : 48 V

1.6 Important FootNotes to Prime Component Data

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Averages

	Estimated Load Data	Winter	Spring /Autumn	Summer	Mean Annual	Units
2.1	Total AC and DC energy required	4.0	57.6	25.2	36.2	MJ/d
2.2	Direct AC load portion	3.6	52.2	19.8	32.0	MJ/d AC
2.3	Direct DC load portion	0.4	5.4	5.4	4.2	MJ/d DC
2.4	Required gross DC equivalent	15.6	107.4	62.3	73.4	MJ/d DC
2.5	Total load support time (autonomy via battery storage)	730	51	118	236	hours

PV Performance Data

The power supply at Stokes Point Warden Station is a Gencharger (tm) GenSet hybrid system. A photovoltaic array was not installed.

Genset Performance Data

	Genset power capacity:					
2.8	- installed				15.0	kW AC
2.9	- continuously utilized	10.1	11.4	10.5	10.9	kW AC
2.10	- required for site AC load	0.1	1.4	0.5	0.8	kW AC
2.11	- available for Gencharging	14.9	13.6	14.5	14.2	kW AC
2.12	- applied to Gencharging	10.0	10.0	10.0	10.0	kW AC
2.13	Number of genset start/run/stop/rest cycles	4	104	24	132	cycles
2.14	Time between genset starts	551.7	42.3	92.6	66.6	h/cycle
2.15	Average run time in a cycle	3.9	4.0	4.0	4.0	h/cycle
2.16	Average run time in a day	0.2	2.1	1.0	1.3	h/day
2.17	Duty cycle	1	9	4	6	%
2.18	Fuel consumption - daily	0.6	7.8	3.5	4.9	litres
2.19	Available thermal energy for cogeneration - daily	8.94	119.18	54.14	75.56	MJ
2.20	Genset contribution towards gross DC equivalent	100.0	100.0	100.0	100.0	%

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Totals

	Estimated Load Data	Winter	Spring /Autumn	Summer	Total Annual	Units
2.1	Total AC and DC energy required	0.4	10.5	2.3	13.2	GJ
2.2	Direct AC load portion	0.3	9.6	1.8	11.7	GJ AC
2.3	Direct DC load portion	0.0	1.0	0.5	1.5	GJ DC
2.4	Required gross DC equivalent	0.5	11.6	2.7	14.8	GJ DC
	PV Performance Data					

The power supply at Stokes Point Warden Station is a Gencharger (tm) GenSet hybrid system.

A photovoltaic array was not installed.

	Genset Performance Data					
2.13	Number of genset start/run/stop/rest cycles	4	112	26	142	cycles
2.16	Total run time in a season	15	381	92	489	hours
2.17	Duty cycle	1	9	4	6	%
18	Genset fuel consumption	53	1,425	325	1,803	litres
19	Available thermal energy for cogeneration	0.81	21.86	4.99	27.66	GJ

3.0 ECONOMIC CONSIDERATIONS

3.1 GenSet Annual Operating Cost Estimate* : 4,401 $/year

*Note: This figure includes the costs of fuel, routine maintenance, overhauls, and the replacement of the genset at the end of its useful service life.

3.2 GenSet Service Life Estimate : 50+ years

3.3 Battery Storage Bank Service Life Estimate : 20 years

4.0 SUMMARY

4.1 Design Report Utility

This design report presents a summary of system specifications and resulting performance based on the averages of a wide variety of highly complex, uncertain and dynamic variables provided in part by both the prospective system user and the system designer. Actual system performance shall therefore vary accordingly.

4.2 Waiver of Liability

Every reasonable effort has been made to the best ability of all concerned parties to render this design report as accurate as possible in all respects. However under no circumstances shall any such party be required to assume any liability for damages that may be construed as resulting from the use of this design report.

4.3 Copyright Notification

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STOKES 3.00: INITIAL PHOTOGENSET (tm) SYSTEM

Section A: Clerical Data

1.	Design company	: PHOTRON CANADA INC.
2.	Name of designer	: RLL
3.	Design number	: STOKES-3
4.	Design date	: 88 MR 04
5.	Revision number	: 00
6.	Revision date	: 88 MR 04
7.	Client name	: PARKS CANADA
8.	Site name	: Stokes Point Warden Station
9.	Type of system	: Photogenset (tm) PV/GenSet hybrid
10.	Design notes 1	: Initial system sizing.
11.	2	: Sizing allows for use of (1) 24 VDC freezer unit.
12.	3	: Battery state of charge operating regime @ 20-80%.
13.	4	:
14.	5	:
15.	6	:
16.	7	:
17.	8	:
18.	9	:

Section B: Load Data

1.	Required daily DC load energy:	- winter	:	0.43 MJ/d DC
2.		- spring/autumn	:	5.40 MJ/d DC
3.		- summer	:	5.40 MJ/d DC
4.	Required daily AC load energy	- winter	:	3.60 MJ/d AC
5.		- spring/autumn	:	52.20 MJ/d AC
6.		- summer	:	19.80 MJ/d AC

Section C: Generator Set Data

1.	Size of generator set ('genset')	: 15 kW AC
2.	Genset electrical output	: 120/240 VAC, single phase, 60 Hz
3.	Elevation of Stokes Point Warden Statio	: 30 m above sea level
4.	Genset output derating factor	: 0 %
5.	Reason for genset derating factor	: No derating factor
6.	Type of fuel used in genset	: #2 diesel
7.	Genset #2 diesel - at no load	: 1.90 litres/hour
8.	consumption: - at 25% load	: 2.25 litres/hour
9.	- at 50% load	: 2.80 litres/hour
10.	- at 75% load	: 3.70 litres/hour
11.	- at 100% load	: 4.70 litres/hour

12.	Price of #2 diesel at Stokes Point Ward:	2.250 $/litre
13.	Genset - routine maintenance	: 100 $ per interval
14.	maintenance - overhaul	: 5,000 $ per overhaul
15.	costs: - total replacement	: 11,500 $ per replacement
16.	Genset - routine maintenance	: 340 hours
17.	maintenance - overhaul	: 25,000 hours
18.	intervals: - total replacement	: 50,000 hours
19.	Fraction of total AC load directly connected to the running genset	: 100 %

Section D: Inverter Data

1.	AC loads will be supplied by	: an inverter
2.	Number of non-synchronized inverter modules	: 1
3.	Total 30 minute power rating for all inverter modules combined	: 2.7 kW AC

Inverter module electrical characteristics

4.	10 second surge rating	: 6 kW AC
5.	Average DC to AC conversion efficiency	: 90 %
6.	Nominal DC input voltage	: 48 volts DC
7.	Electrical output	: 120 VAC, single phase, 60 Hz
8.	Low DC input voltage cutoff threshold	: 42 volts DC

Section E: Photovoltaic Data

1.	Method of determining PV to the system	: calculations based on specified contribution %	
2.	Number of peak sunlight hours on	- winter	: 0.1 hours
3.	the tilted array on an average	- spring/autumn	: 3.6 hours
4.	day at Stokes Point Warden Station	- summer	: 5.2 hours
5.	Average daytime ambient air	- winter	: -20.0 C
6.	temperature between 08h and 16h	- spring/autumn	: 5.0 C
7.	at Stokes Point Warden Station:	- summer	: 15.0 C
8.	PV module data	Maximum power point voltage	: 16.0 volts DC
9.	at 25 C:	Maximum power point current	: 2.94 amperes DC
10.	Number of PV modules to be used		: 4
11.	Season for which the PV array is to provide the specified daily load requirements		: summer
12.	Fraction of the required daily load energy which the PV array is to provide in the summer		: 85 %

Section F: Battery and Battery Charger Data

1.	Number of series-wired 2 VDC (nominal) battery cells		: 24
2.	Battery state of charge (BSOC)	- started	: 20.0 %
3.	thresholds at which the genset is:	- stopped	: 80.0 %
4.	Average ambient air temperatures	- winter	: -25.0 C
5.	that the battery bank will	- spring/autumn	: 20.0 C
6.	experience:	- summer	: 25.0 C
7.	Method of determining the size of the battery bank		: automatic

SYSTEM-SPEC will calculate an optimum size for the battery bank

9.	Specialized genset continuous loading control stategy	: none

SYSTEM-SPEC will calculate an optimum size for the Gencharger

10.	Method of sizing the Gencharger	: automatic

SYSTEM-SPEC will calculate an optimum size for the Gencharger

Designed by : PHOTRON CANADA INC.
Design number : STOKES-3
Revision number : 00
Name of designer : RLL
Effective date : 88 MR 04

Client name : PARKS CANADA
Site name : Stokes Point Warden Station
Site elevation : 30 m above sea level
Type of system : Photogenset (tm) PV/GenSet hybrid

The following design report was prepared for you with SYSTEM-SPEC (tm), Photron's Power System Design Software. All figures expressed are design averages, except where specifically noted otherwise.

1.0 PRIME COMPONENT SUMMARY

1.1 Photovoltaic ('PV') Array
- DC energy source powered by solar radiation

1. Manufacturer's peak power output ratings at 25 C:
   Power : 1,882 watts
   Current : 29.40 amperes
   Voltage : 64.0 volts
2. Total number of PV modules utilized : 40

1.2 Engine Generator ('Gen Set')
- AC energy source powered by fossil fuel

1. Manufacturer's nominal peak power output rating : 15 kW AC
2. Site installed peak power output rating* : 15 kW AC
3. AC output power configuration : 120/240 VAC, single phase, 60 Hz
4. Type of fuel used : #2 diesel
5. Specified operating regime: generator starts at : 20.0 %
   stops at : 80.0 %

*Note: In accordance with genset manufacturer specifications, this value has been derated for the elevation at Stokes Point Warden Station.

1.0 PRIME COMPONENT SUMMARY (continued)

1.3 Gencharger (tm)
- DC energy source powered by the GenSet (AC to DC converter)

1. Manufacturer's nominal peak power output rating	: 10.9 kW DC
2. Site installed average power output rating	: 8.7 kW DC
3. AC input power configuration	: 240 VAC, single phase, 60 Hz

1.4 Battery Storage Bank
- storage medium for DC energy

1. Manufacturer's nominal 25 C 6 h capacity rating	: 162 MJ DC
2. Minimum site installed capacity rating	: 156 MJ DC
3. Total number of cells per series string	: 24
4. Typical state of charge operating regime	: 20 to 80 %

1.5 Power Inverter
- AC energy source powered by DC electricity (DC to AC converter)

1. Manufacturer's nominal peak output rating at 25 C:	
30 minute continuous power	: 2.7 kW AC
10 second surge power	: 6 kW AC
2. Number of non-synchronized inverter units	: 1
3. AC output power configuration	: 120 VAC, single phase, 60 Hz
4. Nominal DC input voltage	: 48 V

1.6 Important FootNotes to Prime Component Data

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Averages

	Estimated Load Data	Winter	Spring /Autumn	Summer	Mean Annual	Units
2.1	Total AC and DC energy required	4.0	57.6	25.2	36.2	MJ/d
2.2	Direct AC load portion	3.6	52.2	19.8	32.0	MJ/d AC
2.3	Direct DC load portion	0.4	5.4	5.4	4.2	MJ/d DC
2.4	Required gross DC equivalent	4.4	63.4	28.8	40.1	MJ/d DC
2.5	Total load support time (autonomy via battery storage)	678	47	110	219	hours
	PV Performance Data					
2.6	PV derived DC load energy	0.50	17.93	25.90	15.63	MJ/d DC
2.7	PV contribution towards gross DC equivalent	11.2	28.3	89.9	39.0	%
	Genset Performance Data					
	Genset power capacity:					
2.8	- installed				15.0	kW AC
2.9	- continuously utilized	10.1	11.4	10.5	10.9	kW AC
2.10	- required for site AC load	0.1	1.4	0.5	0.8	kW AC
2.11	- available for Gencharging	14.9	13.6	14.5	14.2	kW AC
2.12	- applied to Gencharging	10.0	10.0	10.0	10.0	kW AC
2.13	Number of genset start/run/stop/rest cycles	4	82	3	89	cycles
2.14	Time between genset starts	576.8	53.3	781.5	98.5	h/cycle
2.15	Average run time in a cycle	3.7	3.7	3.7	3.7	h/cycle
2.16	Average run time in a day	0.2	1.5	0.1	0.8	h/day
2.17	Duty cycle	1	6	0	3	%
2.18	Fuel consumption - daily	0.5	5.6	0.4	3.0	litres
2.19	Available thermal energy for cogeneration - daily	7.95	85.72	5.47	46.29	MJ
2.20	Genset contribution towards gross DC equivalent	88.8	71.7	10.1	61.0	%

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Totals

	Estimated Load Data	Winter	Spring /Autumn	Summer	Total Annual	Units
2.1	Total AC and DC energy required	0.4	10.5	2.3	13.2	GJ
2.2	Direct AC load portion	0.3	9.6	1.8	11.7	GJ AC
2.3	Direct DC load portion	0.0	1.0	0.5	1.5	GJ DC
2.4	Required gross DC equivalent	0.4	11.6	2.6	14.7	GJ DC
	PV Performance Data					
2.6	PV derived DC load energy	0.04	3.28	2.38	5.71	GJ DC
	Genset Performance Data					
2.13	Number of genset start/run/stop/rest cycles	4	82	3	89	cycles
2.16	Total run time in a season	14	274	9	297	hours
2.17	Duty cycle	1	6	0	3	%
2.18	Genset fuel consumption	47	1,023	33	1,102	litres
2.19	Available thermal energy for cogeneration	0.72	15.69	0.50	16.91	GJ

3.0 ECONOMIC CONSIDERATIONS

3.1 GenSet Annual Operating Cost Estimate* : 2,695 $/year

*Note: This figure includes the costs of fuel, routine maintenance, overhauls, and the replacement of the genset at the end of its useful service life.

3.2 GenSet Service Life Estimate : 50+ years

3.3 Battery Storage Bank Service Life Estimate : 20 years

4.0 SUMMARY

4.1 Design Report Utility

This design report presents a summary of system specifications and resulting performance based on the averages of a wide variety of highly complex, uncertain and dynamic variables provided in part by both the prospective system user and the system designer. Actual system performance shall therefore vary accordingly.

4.2 Waiver of Liability

Every reasonable effort has been made to the best ability of all concerned parties to render this design report as accurate as possible in all respects. However under no circumstances shall any such party be required to assume any liability for damages that may be construed as resulting from the use of this design report.

4.3 Copyright Notification

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STOKES 3.01: OPTIMIZED PHOTOGENSET (tm) SYSTEM

Section A: Clerical Data

1.	Design company	: PHOTRON CANADA INC.
2.	Name of designer	: RLL
3.	Design number	: STOKES-3
4.	Design date	: 88 MR 04
5.	Revision number	: 01
6.	Revision date	: 88 MR 04
7.	Client name	: PARKS CANADA
8.	Site name	: Stokes Point Warden Station
9.	Type of system	: Photogenset (tm) PV/GenSet hybrid
10.	Design notes 1	: Adjusted PV array capacity simulation.
11.	2	: Sizing allows for use of (1) 24 VDC freezer unit.
12.	3	: Battery state of charge operating regime @ 20-80%.
13.	4	:
14.	5	:
15.	6	:
16.	7	:
17.	8	:
18.	9	:

Section B: Load Data

1.	Required daily DC load energy:	- winter	:	0.43 MJ/d DC
2.		- spring/autumn	:	5.40 MJ/d DC
3.		- summer	:	5.40 MJ/d DC
4.	Required daily AC load energy	- winter	:	3.60 MJ/d AC
5.		- spring/autumn	:	52.20 MJ/d AC
6.		- summer	:	19.80 MJ/d AC

Section C: Generator Set Data

1.	Size of generator set ('genset')	: 15 kW AC
2.	Genset electrical output	: 120/240 VAC, single phase, 60 Hz
3.	Elevation of Stokes Point Warden Statio	: 30 m above sea level
4.	Genset output derating factor	: 0 %
5.	Reason for genset derating factor	: No derating factor
6.	Type of fuel used in genset	: #2 diesel
7.	Genset #2 diesel - at no load	: 1.90 litres/hour
8.	consumption: - at 25% load	: 2.25 litres/hour
9.	- at 50% load	: 2.80 litres/hour
10.	- at 75% load	: 3.70 litres/hour
11.	- at 100% load	: 4.70 litres/hour

12.	Price of #2 diesel at Stokes Point Ward:	2.250 $/litre
13.	Genset - routine maintenance	: 100 $ per interval
14.	maintenance - overhaul	: 5,000 $ per overhaul
15.	costs: - total replacement	: 11,500 $ per replacement
16.	Genset - routine maintenance	: 340 hours
17.	maintenance - overhaul	: 25,000 hours
18.	intervals: - total replacement	: 50,000 hours
19.	Fraction of total AC load directly connected to the running genset	: 100 %

Section D: Inverter Data

1.	AC loads will be supplied by	: an inverter
2.	Number of non-synchronized inverter modules	: 1
3.	Total 30 minute power rating for all inverter modules combined	: 2.7 kW AC

Inverter module electrical characteristics

4.	10 second surge rating	: 6 kW AC
5.	Average DC to AC conversion efficiency	: 90 %
6.	Nominal DC input voltage	: 48 volts DC
7.	Electrical output	: 120 VAC, single phase, 60 Hz
8.	Low DC input voltage cutoff threshold	: 42 volts DC

Section E: Photovoltaic Data

1.	Method of determining PV to the system		: calculations based on specified # of modules
2.	Number of peak sunlight hours on	- winter	: 0.1 hours
3.	the tilted array on an average	- spring/autumn	: 3.6 hours
4.	day at Stokes Point Warden Station	- summer	: 5.2 hours
5.	Average daytime ambient air	- winter	: -20.0 C
6.	temperature between 08h and 16h	- spring/autumn	: 5.0 C
7.	at Stokes Point Warden Station:	- summer	: 15.0 C
8.	PV module data	Maximum power point voltage	: 16.0 volts DC
9.	at 25 C:	Maximum power point current	: 2.94 amperes DC
10.	Number of PV modules to be used		: 32

Section F: Battery and Battery Charger Data

1.	Number of series-wired 2 VDC (nominal) battery cells		: 24
2.	Battery state of charge (BSOC)	- started	: 20.0 %
3.	thresholds at which the genset is:	- stopped	: 80.0 %
4.	Average ambient air temperatures	- winter	: -25.0 C
5.	that the battery bank will	- spring/autumn	: 20.0 C
5.	experience:	- summer	: 25.0 C
	Method of determining the size of the battery bank		: automatic

SYSTEM-SPEC will calculate an optimum size for the battery bank

9.	Specialized genset continuous loading control stategy	: none
	SYSTEM-SPEC will calculate an optimum size for the Gencharger	
10.	Method of sizing the Gencharger	: automatic

SYSTEM-SPEC will calculate an optimum size for the Gencharger

Designed by	: PHOTRON CANADA INC.
Design number	: STOKES-3
Revision number	: 01
Name of designer	: RLL
Effective date	: 88 MR 04
Client name	: PARKS CANADA
Site name	: Stokes Point Warden Station
Site elevation	: 30 m above sea level
Type of system	: Photogenset (tm) PV/GenSet hybrid

The following design report was prepared for you with SYSTEM-SPEC (tm), Photron's Power System Design Software. All figures expressed are design averages, except where specifically noted otherwise.

1.0 PRIME COMPONENT SUMMARY

1.1 Photovoltaic ('PV') Array
- DC energy source powered by solar radiation

1. Manufacturer's peak power output ratings at 25 C:
   - Power : 1,505 watts
   - Current : 23.52 amperes
   - Voltage : 64.0 volts
2. Total number of PV modules utilized : 32

1.2 Engine Generator ('Gen Set')
- AC energy source powered by fossil fuel

1. Manufacturer's nominal peak power output rating : 15 kW AC
2. Site installed peak power output rating* : 15 kW AC
3. AC output power configuration : 120/240 VAC, single phase, 60 Hz
4. Type of fuel used : #2 diesel
5. Specified operating regime: generator starts at : 20.0 %
   stops at : 80.0 %

*Note: In accordance with genset manufacturer specifications, this value has been derated for the elevation at Stokes Point Warden Station.

1.0 PRIME COMPONENT SUMMARY (continued)

1.3 Gencharger (tm)
- DC energy source powered by the GenSet (AC to DC converter)

1. Manufacturer's nominal peak power output rating	: 10.9 kW DC
2. Site installed average power output rating	: 8.7 kW DC
3. AC input power configuration	: 240 VAC, single phase, 60 Hz

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1.4 Battery Storage Bank
- storage medium for DC energy

1. Manufacturer's nominal 25 C 6 h capacity rating	: 162 MJ DC
2. Minimum site installed capacity rating	: 156 MJ DC
3. Total number of cells per series string	: 24
4. Typical state of charge operating regime	: 20 to 80 %

1.5 Power Inverter
- AC energy source powered by DC electricity (DC to AC converter)

1. Manufacturer's nominal peak output rating at 25 C:	
30 minute continuous power	: 2.7 kW AC
10 second surge power	: 6 kW AC
2. Number of non-synchronized inverter units	: 1
3. AC output power configuration	: 120 VAC, single phase, 60 Hz
4. Nominal DC input voltage	: 48 V

1.6 Important FootNotes to Prime Component Data

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Averages

	Estimated Load Data	Winter	Spring /Autumn	Summer	Mean Annual	Units
2.1	Total AC and DC energy required	4.0	57.6	25.2	36.2	MJ/d
2.2	Direct AC load portion	3.6	52.2	19.8	32.0	MJ/d AC
2.3	Direct DC load portion	0.4	5.4	5.4	4.2	MJ/d DC
2.4	Required gross DC equivalent	4.4	63.4	28.6	40.1	MJ/d DC
2.5	Total load support time (autonomy via battery storage)	678	47	110	219	hours
	PV Performance Data					
2.6	PV derived DC load energy	0.47	17.08	24.67	14.89	MJ/d DC
2.7	PV contribution towards gross DC equivalent	10.7	26.9	86.2	37.2	%
	Genset Performance Data					
	Genset power capacity:					
2.8	- installed				15.0	kW AC
2.9	- continuously utilized	10.1	11.4	10.5	10.9	kW AC
10	- required for site AC load	0.1	1.4	0.5	0.8	kW AC
11	- available for Gencharging	14.9	13.6	14.5	14.2	kW AC
2.12	- applied to Gencharging	10.0	10.0	10.0	10.0	kW AC
2.13	Number of genset start/run/stop/rest cycles	4	84	4	91	cycles
2.14	Time between genset starts	573.3	52.4	576.5	95.8	h/cycle
2.15	Average run time in a cycle	3.7	3.7	3.7	3.7	h/cycle
2.16	Average run time in a day	0.2	1.5	0.1	0.8	h/day
2.17	Duty cycle	1	6	1	3	%
2.18	Fuel consumption - daily	0.5	5.7	0.5	3.1	litres
2.19	Available thermal energy for cogeneration - daily	8.00	87.33	7.48	47.61	MJ
2.20	Genset contribution towards gross DC equivalent	89.3	73.1	13.8	62.8	%

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Totals

	Estimated Load Data	Winter	Spring /Autumn	Summer	Total Annual	Units
2.1	Total AC and DC energy required	0.4	10.5	2.3	13.2	GJ
2.2	Direct AC load portion	0.3	9.6	1.8	11.7	GJ AC
2.3	Direct DC load portion	0.0	1.0	0.5	1.5	GJ DC
2.4	Required gross DC equivalent	0.4	11.6	2.6	14.6	GJ DC
	PV Performance Data					
2.6	PV derived DC load energy	0.04	3.13	2.27	5.44	GJ DC
	Genset Performance Data					
2.13	Number of genset start/run/stop/rest cycles	4	84	4	91	cycles
2.16	Total run time in a season	14	279	13	305	hours
2.17	Duty cycle	1	6	1	3	%
2.18	Genset fuel consumption	47	1,042	45	1,134	litres
2.19	Available thermal energy for cogeneration	0.72	15.98	0.69	17.39	GJ

3.0 ECONOMIC CONSIDERATIONS

3.1 GenSet Annual Operating Cost Estimate* : 2,772 $/year

*Note: This figure includes the costs of fuel, routine maintenance, overhauls, and the replacement of the genset at the end of its useful service life.

3.2 GenSet Service Life Estimate : 50+ years

3.3 Battery Storage Bank Service Life Estimate : 20 years

4.0 SUMMARY

4.1 Design Report Utility

This design report presents a summary of system specifications and resulting performance based on the averages of a wide variety of highly complex, uncertain and dynamic variables provided in part by both the prospective system user and the system designer. Actual system performance shall therefore vary accordingly.

4.2 Waiver of Liability

Every reasonable effort has been made to the best ability of all concerned parties to render this design report as accurate as possible in all respects. However under no circumstances shall any such party be required to assume any liability for damages that may be construed as resulting from the use of this design report.

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SNARE 1.01: OPTIMIZED PHOTOGENSET (tm) SYSTEM

Section A: Clerical Data

1.	Design company	: PHOTRON CANADA INC.
2.	Name of designer	: RLL
3.	Design number	: SNARE-01
4.	Design date	: 88 MR 01
5.	Revision number	: 01
6.	Revision date	: 88 MR 01
7.	Client name	: Northland Utilities
8.	Site name	: Snare Lake - Trout Lake
9.	Type of system	: Photogenset (tm) PV/GenSet hybrid
10.	Design notes 1	: Revised daily AC load figures (per actual +20%)
11.	2	:
12.	3	:
13.	4	:
14.	5	:
15.	6	:
16.	7	:
17.	8	:
18.	9	:

Section B: Load Data

1.	Required daily DC load energy:	- winter	:	0.00 MJ/d DC
2.		- spring/autumn	:	0.00 MJ/d DC
3.		- summer	:	0.00 MJ/d DC
4.	Required daily AC load energy	- winter	:	1,227.60 MJ/d AC
5.		- spring/autumn	:	788.40 MJ/d AC
6.		- summer	:	810.00 MJ/d AC

Section C: Generator Set Data

1.	Size of generator set ('genset')	: 82.5 kW AC
2.	Genset electrical output	: 120/208 VAC, three phase, 60 Hz
3.	Elevation of Snare Lake - Trout Lake	: 488 m above sea level
4.	Genset output derating factor	: 4 %
5.	Reason for genset derating factor	: ALTITUDE
6.	Type of fuel used in genset	: #2 diesel
7.	Genset #2 diesel - at no load	: 6.00 litres/hour
8.	consumption: - at 25% load	: 6.40 litres/hour
9.	- at 50% load	: 9.50 litres/hour
10.	- at 75% load	: 13.10 litres/hour
11.	- at 100% load	: 17.70 litres/hour
12.	Price of #2 diesel at Snare Lake - Trou	: 0.410 $/litre
13.	Genset - routine maintenance	: 200 $ per interval
14.	maintenance - overhaul	: 10,000 $ per overhaul
15.	costs: - total replacement	: 25,000 $ per replacement
16.	Genset - routine maintenance	: 340 hours
17.	maintenance - overhaul	: 25,000 hours
18.	intervals: - total replacement	: 50,000 hours
19.	Fraction of total AC load directly connected to the running genset	: 100 %

Section D: Inverter Data

1.	AC loads will be supplied by	: an inverter
2.	Number of non-synchronized inverter modules	: 1
3.	Total 30 minute power rating for all inverter modules combined	: 24 kW AC

Inverter module electrical characteristics

4.	10 second surge rating	: 25 kW AC
5.	Average DC to AC conversion efficiency	: 87 %
6.	Nominal DC input voltage	: 120 volts DC
7.	Electrical output	: 120/208 VAC, three phase, 60 Hz
8.	Low DC input voltage cutoff threshold	: 90 volts DC

Section E: Photovoltaic Data

1.	Method of determining PV to the system		: calculations based on specified contribution %
2.	Number of peak sunlight hours on	- winter	: 0.4 hours
3.	the tilted array on an average	- spring/autumn	: 3.3 hours
4.	day at Snare Lake - Trout Lake:	- summer	: 4.9 hours
5.	Average daytime ambient air	- winter	: -20.0 C
6.	temperature between 08h and 16h	- spring/autumn	: 5.0 C
7.	at Snare Lake - Trout Lake:	- summer	: 15.0 C
8.	PV module data	Maximum power point voltage	: 16.0 volts DC
9.	at 25 C:	Maximum power point current	: 2.94 amperes DC
10.	Number of PV modules to be used		: 10
11.	Season for which the PV array is to provide the specified daily load requirements		: spring/autumn
12.	Fraction of the required daily load energy which the PV array is to provide in the spring/autumn		: 35 %

Section F: Battery and Battery Charger Data

1.	Number of series-wired 2 VDC (nominal) battery cells		: 60
2.	Battery state of charge (BSOC)	- started	: 20.0 %
3.	thresholds at which the genset is:	- stopped	: 80.0 %
4.	Average ambient air temperatures	- winter	: 5.0 C
5.	that the battery bank will	- spring/autumn	: 18.0 C
6.	experience:	- summer	: 25.0 C
7.	Method of determining the size of the battery bank		: automatic

SYSTEM-SPEC will calculate an optimum size for the battery bank

9.	Specialized genset continuous loading control stategy	: 90%+ loading
	SYSTEM-SPEC will calculate an optimum size for the Gencharger	
10.	Method of sizing the Gencharger	: automatic

SYSTEM-SPEC will calculate an optimum size for the Gencharger

Designed by	: PHOTRON CANADA INC.
Design number	: SNARE-01
Revision number	: 01
Name of designer	: RLL
Effective date	: 88 MR 01
Client name	: Northland Utilities
Site name	: Snare Lake - Trout Lake
Site elevation	: 488 m above sea level
Type of system	: Photogenset (tm) PV/GenSet hybrid

The following design report was prepared for you with SYSTEM-SPEC (tm), Photron's Power System Design Software. All figures expressed are design averages, except where specifically noted otherwise.

1.0 PRIME COMPONENT SUMMARY

1.1 Photovoltaic ('PV') Array
- DC energy source powered by solar radiation

1. Manufacturer's peak power output ratings at 25 C:
   - Power : 36,691 watts
   - Current : 229.32 amperes
   - Voltage : 160.0 volts
2. Total number of PV modules utilized : 780

1.2 Engine Generator ('Gen Set')
- AC energy source powered by fossil fuel

1. Manufacturer's nominal peak power output rating : 82.5 kW AC
2. Site installed peak power output rating* : 77.3 kW AC
3. AC output power configuration : 120/208 VAC, three phase, 60 Hz
4. Type of fuel used : #2 diesel
5. Specified operating regime: generator starts at : 20.0 %
   stops at : 80.0 %

*Note: In accordance with genset manufacturer specifications, this value has been derated for the elevation at Snare Lake - Trout Lake.

1.0 PRIME COMPONENT SUMMARY (continued)

1.3 Gencharger (tm)
- DC energy source powered by the GenSet (AC to DC converter)
1. Manufacturer's nominal peak power output rating : 92.1 kW DC
2. Site installed average power output rating : 42.1 kW DC
3. AC input power configuration : 208 VAC, three phase, 60 Hz

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1.4 Battery Storage Bank
- storage medium for DC energy
1. Manufacturer's nominal 25 C 6 h capacity rating : 811 MJ DC
2. Minimum site installed capacity rating : 782 MJ DC
3. Total number of cells per series string : 60
4. Typical state of charge operating regime : 20 to 80 %

1.5 Power Inverter
- AC energy source powered by DC electricity (DC to AC converter)
1. Manufacturer's nominal peak output rating at 25 C:
30 minute continuous power : 24 kW AC
10 second surge power : 25 kW AC
2. Number of non-synchronized inverter units : 1
3. AC output power configuration : 120/208 VAC, three phase, 60 Hz
4. Nominal DC input voltage : 120 V

1.6 Important FootNotes to Prime Component Data

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Averages

	Estimated Load Data	Winter	Spring /Autumn	Summer	Mean Annual	Units
2.1	Total AC and DC energy required	1,227.6	788.4	810.0	902.4	MJ/d
2.2	Direct AC load portion	1,227.6	788.4	810.0	902.4	MJ/d AC
2.3	Direct DC load portion	0.0	0.0	0.0	0.0	MJ/d DC
2.4	Required gross DC equivalent	1,411.0	906.2	931.0	1,037.2	MJ/d DC
2.5	Total load support time (autonomy via battery storage)	11	17	16	15	hours
	PV Performance Data					
2.6	PV derived DC load energy	38.85	320.54	475.95	290.08	MJ/d DC
2.7	PV contribution towards gross DC equivalent	2.8	35.4	51.1	28.0	%
	Genset Performance Data					
	Genset power capacity:					
2.8	- installed				77.3	kW AC
.9	- continuously utilized	72.8	71.6	71.7	71.9	kW AC
10	- required for site AC load	32.0	20.5	21.1	23.5	kW AC
2.11	- available for Gencharging	45.3	56.8	56.2	53.8	kW AC
2.12	- applied to Gencharging	40.8	51.1	50.6	48.4	kW AC
2.13	Number of genset start/run/stop/rest cycles	171	192	78	441	cycles
2.14	Time between genset starts	12.7	22.8	28.4	19.9	h/cycle
2.15	Average run time in a cycle	4.5	3.6	3.6	3.9	h/cycle
2.16	Average run time in a day	5.9	2.8	2.1	3.4	h/day
2.17	Duty cycle	25	12	9	14	%
2.18	Fuel consumption - daily	91.8	42.4	32.8	52.2	litres
2.19	Available thermal energy for cogeneration - daily	1408.77	649.88	503.87	800.62	MJ
2.20	Genset contribution towards gross DC equivalent	97.2	64.6	48.9	72.0	%

2.0 SYSTEM OPERATING CHARACTERISTICS - Seasonal Totals

	Estimated Load Data	Winter	Spring /Autumn	Summer	Total Annual	Units
2.1	Total AC and DC energy required	110.8	144.3	74.5	329.6	GJ
2.2	Direct AC load portion	110.8	144.3	74.5	329.6	GJ AC
2.3	Direct DC load portion	0.0	0.0	0.0	0.0	GJ DC
2.4	Required gross DC equivalent	127.3	165.8	85.7	378.8	GJ DC
	PV Performance Data					
2.6	PV derived DC load energy	3.51	58.66	43.79	105.95	GJ DC
	Genset Performance Data					
2.13	Number of genset start/run/stop/rest cycles	171	192	78	441	cycles
2.16	Total run time in a season	534	508	198	1,239	hours
2.17	Duty cycle	25	12	9	14	%
2.18	Genset fuel consumption	8,288	7,753	3,022	19,063	litres
2.19	Available thermal energy for cogeneration	127.14	118.93	46.36	292.43	GJ

3.0 ECONOMIC CONSIDERATIONS

3.1 GenSet Annual Operating Cost Estimate* : 9,660 $/year

*Note: This figure includes the costs of fuel, routine maintenance, overhauls, and the replacement of the genset at the end of its useful service life.

3.2 GenSet Service Life Estimate : 40 years

3.3 Battery Storage Bank Service Life Estimate : 5.9 years

4.0 SUMMARY

4.1 Design Report Utility

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